Improvements to Electromagnetic Propulsion Devices

DESCRIPTION

[Para 1] Cross Reference to Related Applications.

This utility patent application is directly related to pending utility patent application 10/707,607 filed by the applicant on December 24, 2003.

[Para 2] Background of the Invention.

[Para 3] Field of the invention.

[Para 4] The embodiments of this invention are related to electromagnetic propulsion devices such as rail guns. In rail guns, magnetic fields perpendicular to the electrical current through an armature interacts with the current creating forces on the armature which are perpendicular to both the armature's current and the magnetic fields. The armature of a rail gun is located between and has moving electrical continuity with the gun's parallel power rails and current flow through the armature is resultant a voltage potential between the power rails.

[Para 5] Description of related art.

[Para 6] Devices of this application are improvements to an invention embodiment in the applicant's patent application: 10/707,607. In said embodiment, an armature is electromagnetically propelled from breech to muzzle in the barrel cavity by the interaction of the armature's propulsion bus current with the magnetic fields of the currents in barrel wall conductors located immediately forward and aft said bus during the armature's barrel cavity traverse.

[Para 7] The propulsion bus of armatures for said embodiment is oriented orthogonal the armature's axis and, when in the barrel cavity, to the armature's direction of barrel

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cavity traverse and the barrel cavity's axis. Said propulsion bus extends around most of the armature's perimeter at its surface proximal the barrel cavity's wall surface.

[Para 8] An armature for the device also includes a forward current shunt and an aft current shunt in its surface proximal the barrel cavity surface. With an armature in the barrel cavity, the armature's forward current shunt is located on the muzzle side of the propulsion bus and is electrically insulated from direct electrical continuity with the rest of the armature and the aft current shunt is located on the breech side of the propulsion bus and is also insulated from direct electrical continuity with the rest of the armature except when the propulsion bus-aft shunt circuit means of the device is a current bus in the armature connecting the aft current shunt with the proximal end of the armature's propulsion bus.

[Para 9] The embodiment includes a wall conductor assembly in the barrel cavity wall. The wall conductor assembly is comprised of the multitude of parallel, spaced, equal length barrel wall conductors; *i.e.* wall conductors. The wall conductors are oriented orthogonal the barrel cavity axis and located at or very close to the barrel cavity surface. Said assembly extends the length of the barrel cavity in which the device is extant and includes a barrel bus in the barrel cavity wall. The barrel bus extends parallel the cavity axis its length or has a constant rate of angular displacement at a constant radius about the cavity axis per unite barrel cavity length when the barrel cavity walls have a twist to impart spin to armatures traversing the barrel cavity. Each wall conductor has electrical and physical continuity with a contact means at the barrel cavity at one end and with the barrel bus on its other end. During an armature's traverse of the barrel cavity, wall conductors that are forward the armature's propulsion bus and which have electrical continuity with the armature's forward current shunt are forward wall conductors. Said electrical continuity is extant during the forward shunt's traverse past the cavity locations of each said wall conductor's contact

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means. Wall conductors that are aft the armature's propulsion bus and which have electrical continuity with the armature's aft current shunt are aft wall conductors. Said electrical continuity is extant during the aft shunt's traverse past the cavity locations of each said wall conductor's contact means. The barrel bus maintains electrical continuity between the group of one or more wall conductors comprising the forward wall conductors and the group of one or more wall conductors comprising the aft wall conductors, at any instant, during an armature's traverse of the barrel cavity.

[Para 10] The topic device also has two barrel power rails connected to the terminals of an outside power supply. During an armature's traverse of the barrel cavity one of the power rails has continuous sliding electrical continuity with the armature's forward current shunt and the second barrel power rail has continuous sliding electrical continuity with the proximal end of the armature's propulsion bus.

[Para 11] With an armature in the barrel cavity, a series circuit comprised of the barrel power rail that has sliding continuity with the armature's forward current shunt, the armature's forward current shunt, the forward wall conductors, the wall conductor assembly' barrel bus, the aft wall conductors, the armature's aft current shunt, the propulsion bus-aft shunt circuit means -said circuit means maintains electrical continuity between the armature's aft current shunt and the proximal end of the armature's propulsion bus- , the propulsion bus and the second barrel power rail is extant. With power supplied to the device via connections at the breech end of the power rails, the magnetic fields of the forward and aft wall conductors' currents interact with the current flow in the armature's propulsion bus propelling the armature through the barrel cavity from breech to muzzle.

[Para 12] With the device energized and an armature in the barrel cavity, the magnetic fields of a current element at the intersection of an axis plane [*i.e.* a plane containing the cavity axis] with a conducting wall conductor interacts with the current element at the

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intersection of said plane with the propulsion bus, creating forces therein with cavity axis parallel muzzle directed components that propel the armature in the barrel cavity. The axis plane intersects the propulsion bus a second time when said bus is extant at π radians distance about the armature's axis from the first intersection and the magnetic fields of the topic wall conductor current element interacts with the current element at the second intersection creating forces therein with components parallel the cavity axis and breech directed. The current element at the second intersection is at a significantly greater radius and has a greater deflection angle from the topic wall conductor's current element; therefore, the forces produced in the second intersection can usually be ignored. One of the advantages of this embodiment is that it permits electromagnetic propulsion in a vast array of symmetric and asymmetric cavity and armature profile designs.

[Para 13] The force in newtons on armatures for the topic device with a cylindrical cavity is given by the general simplified equation with a cross product integrand :

$$\text{Force} = 2\left[\ .9 \int_{\beta_0}^{\beta_1} I_{pb}\, r_{pb} \bullet d\theta \ \ X\ (\mu_0\, I_{wc}\ /(2\pi))(\text{Cos}\ \alpha /\ d_{wc-pb})\ \right]$$

[Para 14] I_{pb} is the armature's propulsion bus current. I_{wc} is the total aft wall conductors' current or the total forward wall conductors' current; *i.e.* $I_{pb} = I_{wc}$. The 2 before the bracketed terms accounts for the interaction with the armature's propulsion bus current, I_{pb}, with the magnetic fields' of the currents in both the forward and aft wall conductors creating the armature's propulsion force. The .9 in the bracketed term is an attenuation term compensating for the effect of the magnetic field of a wall conductor's current element on the second propulsion bus's current element, when extant, located π radians arc distance about the armature's axis from the primary intersection. The propulsion bus is at the cylindrical surface of the armature and oriented orthogonal the cavity's and armature's axes at radius r_{pb}. The length in meters of the armature's propulsion bus on whose current

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the wall conductors' magnetic fields act is the integral of $r_{pb}\, d\theta$ through angle $\beta_1 - \beta_0$, where β_0 is the angular location about the armature's axis of the propulsion bus where it has electrical continuity with the propulsion bus-aft shunt circuit means, and β_1 is the angular location about the armature's axis of the propulsion bus at its sliding continuity with the barrel power rail. Permeability of free space, μ_0, is $4\pi \times 10^{-7}$ Henries/meter. The distance between a current element at an axis plane's intersection with a wall conductor and the current element at said axis plane's intersection with armature's propulsion bus is d_{wc-pb} and said distance has deflection angle α from a cavity axis parallel line. The Cos α term is the force component directed parallel the cavity axis. Both d_{wc-pb} and Cos α in the (Cos α)/d_{wc-pb} term vary for each wall conductor as said conductor's contact means are traversed by the armature's current shunt and a mean effective value approximation for (Cos α)/d_{wc-pb} may best be achieved by computer iteration.

Brief Summary of the Invention

[Para 15] The improvements herein disclosed increase the armature's propulsion force per ampere current and/or simplify the device and/or expand the usefulness of the device as follows.

[Para 16] The armature's propulsion bus as a multiple turn coil between its end at the propulsion bus-aft shunt circuit means and its end at the barrel power rail is one said improvement. The propulsion bus coil is about and approximately orthogonal to the armature's axis and located at the armature's surface proximal the cavity's surface when in the barrel cavity. With the device energized and an armature in the barrel cavity, the magnetic fields of a current element at the intersection of an axis plane with a conducting wall conductor interacts with the current element at the proximal intersection of the axis plane with each turn of the propulsion bus coil creating forces therein with muzzle directed axis parallel components; whereas, in the prior art discussed above said plane would

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intersect the propulsion bus only once to effect said propulsion. Therefore, given similar dimensions and like currents, the topic improvement - the armature's propulsion bus including a coil- significantly increases the force on the armature. Consequent the sum of each said wall conductor's current element and its magnetic fields' interaction with its respective current element in each turn of the propulsion bus, the armature is propelled in the barrel cavity from breech to muzzle.

[Para 17] The use of wall conductors that have, between their ends with contact means at the barrel cavity and their ends with electrical continuity the barrel bus, multiple turn coils about the barrel cavity that are oriented approximately orthogonal the cavity axis is another improvement. An axis plane through a wall conductor has a magnetic field source current element at the plane's intersection with each turn of the wall conductor coil; therefore, the magnetic field density acting on the current element at the intersection of the axis plane with the propulsion bus is greatly increased. With the device energized and an armature in the barrel cavity, the magnetic fields of each current element at the intersection of an axis plane with each turn of a conducting wall conductor interacts with the current element at the intersection of said plane with the armature's propulsion bus creating forces therein with cavity axis parallel muzzle directed components. The sum of wall conductor coil's magnetic fields throughout the propulsion bus arc extent of the barrel cavity, acting on their respective propulsion bus current elements, combine to propel the armature in the barrel cavity.

[Para 18] In another embodiment of the device, both the armature's propulsion bus and the wall conductors include multiple turn coils about and approximately orthogonal the armature's axis and barrel cavity's axis, respectively. This arrangement significantly increases the force per ampere acting on the armature via the enhanced magnetic field density due to the wall conductors' coils acting on the greatly increased length of the

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armature's propulsion bus coil. With the device energized and an armature in the barrel cavity, the magnetic fields due to the current element at the intersection of an axis plane with each turn of a wall conductor's coil interact collectively with the propulsion bus current element at the axis plane's intersection with each turn of the propulsion bus's coil to propel the armature in the barrel cavity and the sum of said magnetic fields throughout the 2π arc extent of the barrel cavity, acting on their respective current element in each turn of the propulsion bus's coil, combine to propel the armature in the barrel cavity.

[Para 19] In another embodiment of the device, the armature's propulsion bus has one external power supply and the forward and aft wall conductors another; *i.e.* the armature's propulsion bus and wall conductors are no longer elements is the same series circuit. The electromagnetic propulsion devices have 2 pairs of power rail not both the same; i.e. three or four barrel power rails. Two power rails supply the armature's propulsion bus circuit and two power rails supply the wall conductor circuit. With the device energized and an armature in the barrel cavity, the wall conductors are permitted much larger currents than the armature's propulsion bus and subsequently create greater magnetic field densities acting on the armature's propulsion bus current. The propulsion bus, no longer electrically in series with the wall conductors, is permitted smaller currents to reduce its mass and increase the portion of the armature's barrel cavity traverse time it remains viable as a conductor.

[Para 20] With the device's wall conductors and armature's propulsion bus powered by separate and mutually isolated power circuits, useful applications of the device are expanded to include bidirectional electromagnetic motors and actuators. With an isolated power supply circuit for each the armature's propulsion bus circuit and the wall conductor circuit and the armature and barrel modified for a low friction long life use as a bidirectional

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actuator or motor, the powered cavity traverse by the armature in the actuator or motor is reversed by reversing the polarity in one of the two isolated power supply circuits.

[Para 21] Improvements disclosed herein also include embodiments with reduced number of essential elements. In said embodiments, the function of the armature's propulsion bus and its barrel and armature current supply circuit elements are replaced by a permanent magnet in the armature that is polarized parallel to the armature's axis. Said magnet polarity interacts with the polarity of the forward and aft wall conductor (coils) magnetic fields to propel the armature in the barrel cavity. *E.g.* With the north pole of the armature's magnet towards the muzzle and the south pole towards the breech, and the current direction in the coil of each wall conductor comprising the forward wall conductors at any instant in the direction that puts the south pole of said coil proximal the north pole of the armature's magnet, there are forces of attraction there between which propels the armature in the barrel cavity towards the muzzle. The current direction in the coil of each wall conductor comprising the aft wall conductors, at said instant, is opposite that in the forward wall conductors coil and the south pole said coil is proximal the south pole of the armature's magnet creating forces of repulsion there between which also propels the armature in the barrel cavity towards the muzzle.

[Para 22] The permanent magnet embodiment discussed above can also be used as a bidirectional electromagnetic actuator or motor, with the armature and barrel modified for low friction long life use as such. In the topic device, reversing the direction of the powered traverse of the barrel cavity by the armature at any instant is accomplished by reversing the polarity of the wall conductor power supply circuit.

[Para 23] The equations and examples herein are intended as aides to practitioners of the arts relevant the topic devices and are not part of the claimed devices, and the degree of

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their veracity is not intended to reflect adversely on the veracity, spirit, intent, merit or scope of this application for letters of patent.

[Para 24] **Brief Description of the Several Views of the Drawings**

Figure 1 is an oblique cutaway view of the essential current path elements in patent application 10/707/607 embodiment herein improve upon.

Figure 2 is an oblique view of an assembled embodiment of the invention which uses armatures having a propulsion bus coil and a current bus as propulsion bus-aft shunt circuit means.

Figure 3 is a view into the muzzle end of figure 2 at a15° angle to the cavity's axis.

Figure 4 is an oblique view of the device in figure 2, disassembled.

Figure 5 is an oblique view of an assembled armature for the device in figure 2.

Figure 6 is an oblique view of the armature in figure 5 disassembled.

Figure 7 is an oblique cutaway view of the device in figure 2 to illustrate its current path.

Figure 8 is an oblique cutaway view of a device with wall conductor coils, a third barrel rail as part of the propulsion bus-aft shunt circuit means and that uses single turn propulsion bus armatures.

Figure 9 is an oblique cutaway view of a device with wall conductor coils, a third barrel rail as part of the propulsion bus-aft shunt circuit means, and that uses armatures with propulsion bus coils.

Figure 10 is an oblique view of an assembled armature for the device in figure 9.

Figure 11 is an oblique view of the armature in figure 10 disassembled.

Figure 12 is an oblique cutaway view of the device in figure 9 to illustrate its current path.

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Figure 13 is an oblique cutaway view of a device wherein the armature's propulsion bus and the wall conductors are in separate circuits supplied by of two pairs of power rails, not both the same, which includes a common barrel power rail.

Figure 14 is an oblique cutaway view of an armature for the device in figure 13.

Figure 15 is an oblique cutaway view of a device as in figure 13, but wherein two power rails supply the wall conductor circuit and two addition power rails the propulsion bus circuit.

Figure 16 is an oblique cutaway view of the device in figure 13 but wherein the armature and barrel have been modified for repetitive low friction use as a bidirectional electromagnetic motor or actuator.

Figure 17 is an oblique cutaway view of the armature for the device in figure 16.

Figure 18 is an oblique cutaway view of the device portrayed in figure 15 but modified for repetitive use as a bidirectional electromagnetic actuator or motor.

Figure 19 is an oblique cutaway view of a device wherein the armature's propulsion bus and associated circuitry is replaced by a permanent magnet polarized in the direction of the armature's axis.

Figure 20 is an oblique view of an armature for the device in figure 19.

Figure 21 is an oblique view of the armature in figure 20 disassembled.

Figure 22 is an oblique cutaway view of the device in figure 19 modified for repetitive use as a bidirectional electromagnetic actuator or motor.

Figure 23 is an oblique cutaway view of the armature for the device in figure 22.

Figure 24 is a view up into and towards the breech of a barrel cavity section with twist.

Detailed Description of the Invention

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[Para 25] The designs herein disclosed increase the force on an armature per ampere current and some said designs may be used as bidirectional actuators or motors. Some designs also have a reduction in the number of elements required for its function.

[Para 26] The topic electromagnetic propulsion device of application 10/707,607 has a barrel and a cavity through the barrel with a breech end and a muzzle end. The cavity profile in right section planes through the barrel cavity throughout the cavity's length are uniform (identical within manufacturing limitations); *i.e.* throughout the length of the cavity, the cavity profile in planes perpendicular the cavity axis are alike. With power supplied to the device, armatures in or inserted into the breech end of the cavity are propelled through the cavity towards and out of its muzzle end. The central axis of an armature in the barrel cavity is parallel and close or coincident with the barrel cavity's axis. All armature profiles in right section planes taken to the armature's axis are smaller than the barrel cavity's right section plane profile and a portion of said armature's right section plane profiles are similar to the barrel cavity's profile in a right section plane in shape and slightly undersized thereof to permit unobstructed traverse of the barrel cavity by the armature.

[Para 27] The device has two barrel rails that are power rails. The power rails are of like or similar length, located in the barrel cavity wall along the same length of barrel, parallel each other, and proximal and electrically insulated from each other and each power rail has a continuous surface along its length that is part of the barrel cavity surface and extends the length of the barrel through which the device propels an armature. Each power rail has a connection means for the attachment of circuitry to an outside power source.

[Para 28] The barrel walls also contain a wall conductor assembly; *i.e.* wall assembly. The wall assembly includes a barrel bus that is located in the barrel wall and parallel, of similar length and barrel cavity length location as the power rails. The barrel bus is in close proximity one of said power rails and electrically insulated from both power rails. The wall

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assembly also includes a plurality of equal length parallel wall conductors in the barrel cavity wall which are separated from each other in a distribution along the length of the barrel bus and located at or very near the barrel cavity surface and each wall conductor is physically and electrically continuous with to the barrel bus. Each wall conductor extends from the barrel bus circumscribing, within the barrel cavity wall, most of the cavity to close proximity without contact the barrel power rail distal the barrel bus. At said power rail proximal location, each wall conductor has and is electrically continuous with an electrical contact means at the barrel cavity. Except when an armature's current shunt is located at a wall conductor's contact means, the wall conductors, beyond the barrel bus, are electrically insulated from their surroundings. An armature for the device has a propulsion bus which when in the barrel cavity is oriented therein to travel in close proximity to the wall conductors of the wall conductor assembly and carry current in a direction perpendicular to the cavity axis and parallel to the wall conductors. During an armature's barrel cavity traverse its propulsion bus current flow is perpendicular to the direction of the armature's barrel cavity traverse.

[Para 29] The propulsion bus of an armature in the barrel cavity is within and very close to or at the armature's surface proximal the barrel cavity's surface and extends from its end with electrical continuity the barrel power rail proximal the barrel bus to its end at the propulsion bus-aft shunt circuit means with which it also has electrical continuity. With armature's movement in the barrel cavity, said barrel power rail continuity is sliding.

[Para 30] An armature for the device has a forward current shunt that when in the barrel cavity is located on the muzzle side of the propulsion bus and proximal the power rail distal the wall assembly's barrel bus. The forward current shunt has surface in the armature that has continuous electrical continuity with the wall conductor assembly via the contact means of each wall conductor of the group of one or more wall conductors comprising the forward

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wall conductors, at any instant, at the barrel cavity location of said shunt's surface. Said forward current shunt also has surface with continuous electrical continuity with the proximal power rail via said rail's barrel cavity surface. With an armature's movement in the barrel cavity the above said continuous electrical continuities are continuous sliding electrical continuities.

[Para 31] During an armature's barrel cavity traverse, surface of its forward current shunt has continuous sliding electrical continuity with the wall conductor assembly from breech to muzzle. Said continuity is resultant the continuous sliding electrical continuity said surface has sequentially with successive wall conductors comprising the forward wall conductors of the wall conductor assembly via their contact means as said contact means pass with continuous sliding electrical continuity across the forward current shunt's surface as said surface passes the barrel cavity locations of said contact means. The forward current shunt of an armature in or traversing the barrel cavity thus maintains continuous electrical continuity between the proximal power rail and each wall conductor comprising the forward wall conductors of the wall conductor assembly.

[Para 32] The forward current shunt except for its electrical continuity with the proximal power rail and its electrical continuity via the contact means of each wall conductor of the group of wall conductors comprising the forward wall conductors at any instants is electrically insulated from the rest of the armature and barrel.

[Para 33] The armature also has an aft current shunt that is, with the armature in the barrel cavity, located on the breech side of the armature's propulsion bus and maintains continuous electrical continuity with propulsion bus-aft shunt circuit means and when said means includes a third rail, said shunt, when in the barrel cavity, has surface with continuous electrical continuity said third rail.

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[Para 34] The aft current shunt has surface in the armature that, when in the barrel cavity, has continuous electrical continuity with the wall conductor assembly via the contact means of each wall conductor of the group of one or more wall conductors comprising the aft wall conductors, at any instant, at the barrel cavity location of said shunt surface. With an armature's movement in the barrel cavity the above said continuous electrical continuities are continuous sliding electrical continuities.

[Para 35] During an armature's barrel cavity traverse, surface of its aft current shunt has continuous sliding electrical continuity with the wall conductor assembly from breech to muzzle and said continuity is resultant the continuous sliding electrical continuity said surface has sequentially with successive wall conductors comprising the aft wall conductors of the wall conductor assembly via their contact means as said contact means pass with continuous sliding electrical continuity across the aft current shunt's surface as said surface passes the barrel cavity locations of said contact means.

[Para 36] The aft current shunt of an armature in or traversing the barrel cavity thus maintains continuous electrical continuity between the propulsion bus-aft shunt circuit means and the wall conductors comprising thee aft wall conductors, at any instant, of the wall conductor assembly.

[Para 37] The device has a propulsion bus-aft shunt circuit means that is either a short current bus in the armature that has physical and electrical continuity with both the aft current shunt and the end of the armature's propulsion bus thereto proximal, or a third barrel rail that is of like length, parallel to, and insulated from the power rails and extending through the same barrel length as said power rails and having a continuous barrel cavity surface its length.

[Para 38] When the propulsion bus-aft shunt circuit means includes a third barrel rail, and an armature is in the barrel cavity, continuous electrical continuity is maintained

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between the armature's propulsion bus and aft current shunt via the continuous electrical continuity of the third rail's cavity surface with an aft current shunt's surface and surface on the propulsion bus thereto proximal.

[Para 39] With an armature in the barrel cavity, the armature's propulsion bus, except for its electrical continuity with the barrel power rail and its electrical continuity with the propulsion bus-aft shunt circuit means, is electrically insulated from the rest of the armature and barrel. The armature's aft current shunt, except for its electrical continuity with each wall conductor comprising the aft wall conductors, at any instant, via said conductors' contact means and its electrical continuity with the propulsion bus via the propulsion bus-aft shunt circuit means, is electrically insulated from the rest of the armature and barrel.

[Para 40] With an outside power source connected to the terminals of the power rails and an armature in or inserted into the barrel cavity of the device where said barrel rails and wall assembly are, the electric current path in the device effecting electromagnetic propulsion of the armature in the barrel cavity towards the muzzle is extant and remains so while the armature is completely in the barrel cavity where said rails and wall assembly are. The magnetic fields resultant the electric current in the forward and aft wall conductors of the wall conductor assembly interact with the current flow through the armature's propulsion bus creating forces therein with cavity axis parallel, muzzle directed components which propel the armature in the barrel cavity towards the muzzle.

General Design Considerations

[Para 41] With reference now to the present inventions, when the propulsion bus-aft shunt circuit means is a short current bus in the armature between the aft current shunt and the end of the propulsion bus proximal said shunt, the magnetic fields of the barrel power rails interact with the bus current creating forces therein with components orthogonal to the

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barrel cavity's axis. When armature's current bus is oriented parallel to the armature's axis and when in the barrel cavity located in the barrel cavity midway between the barrel power rails, said orthogonal force components collectively resolve into a tangential force about the armature's axis at the current bus center line radius. Said tangential force is always directed towards the power rail at the forward current shunt and away from the power rail at the armature's propulsion bus. This force might therefore be used to aid armature rotation during traverse of the barrel cavity, rotation which is otherwise effected by the barrel cavity surface. When the propulsion bus-aft shunt circuit means for a barrel cavity traversing armature is comprised of a third barrel rail that has continuous sliding continuity with both the aft current shunt and the armature's propulsion bus said tangential force on the armature is eliminated.

[Para 42] Beyond the barrel bus of the wall conductor assembly, wall conductors are isolated from one another throughout their length when not sharing a common current shunt at their ends distal the barrel bus. Said isolation is effected by insulating barrel material, or insulating coating or sleeves, or less preferably by clearance gaps (air).

[Para 43] There can be one wall conductor or the equivalent sum in cross section areas to one wall conductor, or more in contact with the each armature current shunt.

[Para 44] The forward and the aft wall conductors are each comprised of a group of one or more wall conductors or the equivalent sum in cross section areas to one or more wall conductors whose contact means have continuity with the forward and aft current shunts, respectively, at any instant.

[Para 45] Although the wall conductors of the wall conductor assembles herein illustrated are distributed uniformly along the length of the wall assembly's barrel bus and have constant cross section areas, the wall conductor cross section areas and their spacing might vary along the length of the assembly. *E.g.* In a device where barrel mass and durability are

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design constraints, to avoid wall conductor failure due to prohibitive heat and resistance build up, the cross section area of a wall conductor at the breech end of the cavity might be many times a wall conductor's cross section area at the muzzle. This area variation compensates for the longer wall conductor conduction time intervals at the cavity's breech region. The wall conductor distribution density along the barrel bus might also be greater at the breech than the muzzle end of the barrel cavity; *i.e.* the wall conductors would no longer have a uniform distribution along the barrel bus. The coils of the wall conductors proximal the breech might have many more turns than the coils of wall conductors proximal the muzzle.

[Para 46] For clarity of presentation, the invention embodiments portrayed in the included figures are chemically bonded together in assembly. In practical applications and for quick refurbishment or repair, the embodiments would be assembled using mechanical fastening means well known in the arts.

[Para 47] Molding methods also well known in the arts can be used for barrel, armature fabrication and coil encasement.

[Para 48] When the device is intended to propel armatures as projectiles, an armature's propulsion bus and current shunts whose operational life is measured in milliseconds and fractions thereof can be simple formed pieces of sheet Aluminum or Copper alloy or, mass restrictions permitting, other conducting alloy,.

[Para 49] As a safety measure in armatures used as projectiles, the propulsion bus could be designed to melt or burst open from heat after the anticipated armature's barrel cavity traverse time has elapsed.

[Para 50] Voids and masses necessary to locate an armature's center of mass for in flight stability are not shown in the figures.

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[Para 51] The armatures and barrel for the devices are made of electrically non-conducting materials such as SiC or high strength proprietary plastics. The wall conductor assembly and barrel rails are made of good conducting material such as copper, aluminum or iron alloys.

[Para 52] The wall conductors experience rapid field reversal during barrel cavity traverse by an armature and any residual magnetic energy (polarization) stored in proximal structure material will have attenuating effects on the wall conductor's magnetic field.

[Para 53] Generally, in regards the various embodiments of the invention, surfaces of elements of the invention having sliding electrical continuity with other elements thereof might be treated and/or machined and/or formed to effect a smooth more effect sliding continuity; *e.g.* a surface with boundary edges could have those edged rounded and the surface could be treated with low friction conducting substances and/or textured to assure a correct current path when elevated voltages are extant in the invention.

[Para 54] The armature may have variations in its surface extruded parallel to its axis; *e.g.* Corrugated surfaces with troughs parallel to the armature's axis.

[Para 55] The meaning of sliding electrical continuity between elements in the invention is expanded herein to include arrangements to effect electrical continuity between relatively moving elements using conducting rollers or roller balls which are retained in one said element and which have low friction electrically conducting contact with a surface on the second element.

[Para 56] A coil's current direction and/or winding direction is always indicated, unless otherwise noted, when looking from the muzzle end towards the breech end of the coil or part in which the coil is mounted and indicated as cw for clockwise current circulation (counter clockwise electron flow) or direction the coil winding about the coil axis and ccw

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for counter clockwise current circulation (clockwise electron flow) and coil winding about the coil axis.

[Para 57] The barrel and its cavity used by the device may extend at the muzzle and/or breech beyond the electromotive propulsion elements of the invention and in said extensions the armature may or may not be acted on by additional motive, orientation, and material modifying devices or other devices not part of the invention; *i.e.* the invention may share a common barrel and barrel cavity with other devices not necessary to or part of the invention.

[Para 58] TERMINOLOGY.

[Para 59] ***Aft wall conductors:*** With an armature for the device in the barrel cavity, the aft wall conductors is the group of one or more consecutive wall conductors which have at any instant continuous, or continuous sliding, electrical continuity via their contact means at the barrel cavity, with an armature's aft current shunt surface at the barrel cavity location of said contact means.

[Para 60] ***Armature:*** The armatures herein portrayed are either single use projectiles or the motion imparting elements in bidirectional actuators or motors. The profile shape of all right section planes through the armature at the propulsion bus are like but slightly undersized the common barrel cavity profile in right section planes. Although the armatures illustrated are projectiles or actuator and motor armature elements, alternative uses might also include reusable transport propulsion means wherein the armature of the invention is constructed as a reusable carriage of a transport system utilizing the claimed invention at least partially for propulsion and in which the barrel, barrel cavity, etc, might have turns of various radii and the armature carriage of the system is formed or deformable to negotiate said turns.

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[Para 61] *Armature's Breech End and Muzzle End:* When an armature is properly mounted for propulsion in the barrel cavity its breech end is its end located closest to the cavity's breech end and its muzzle end is its end located closest the cavity's muzzle end.

[Para 62] *Armature Central Axis:* The armature central axis is the line through the area centroid centers of the armature profile in right sections taken through that portion of the armature whose profiles have shape like but slightly undersized the barrel cavity's right section profile. The armature central axis in the barrel cavity is parallel and closely proximal the barrel cavity central axis or coincident said axis.

[Para 63] *Axis plane:* An axis plane contains the cavity axis and the cavity axis is the only boundary of said planes. An axis plane's location is determined by the axis and the angular displacement and direction about the axis with reference to given point in space not in the axis. *E.g.* Looking from the muzzle towards the breech, the line of the axis plane is 0.34 radians clockwise (about the cavity axis) from the barrel bus axis.

[Para 64] *Barrel Cavity Wall and Barrel Cavity:* The barrel cavity wall is comprised of the barrel from the barrel cavity's outer radius outward and in the invention contains the barrel rails and wall conductor assembly and may be a continuous section of a longer barrel and barrel cavity. The longer barrel and barrel cavity might contain sections before and/or after the barrel and barrel cavity of the invention with functions unrelated to the claimed device. *E.g.* Sections in front of the breech end of the invention barrel might be a simple fixed or expendable cap closing the breech end of the cavity, or part of a rapid breech load mechanism, mount expendable pneumatic armature injection cartridges, or an armature injection means using an embodiment of the invention to inject an armature into the barrel cavity, and/or may add or modify propellant or explosive payload or a guidance system of the armature, etc, and barrel and barrel cavity sections beyond the muzzle of the invention may include a simple frangible end cap protection from the elements, initiate chemical

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propulsion of the armature, or include other electromagnetic propulsion means and/or a safe-unsafe trigger mechanism for an explosive payload in the armature, etc..

[Para 65] ***Barrel Bus and Rail Length and Location:*** Lengths and locations along the barrel cavity length of barrel rails might vary slightly from one another in a design; *i.e.* the two power rails extant in embodiments of the invention, along with the barrel rail of the propulsion bus-aft shunt circuit means when extant, and the barrel bus of the wall conductor assembly might have slight variations in length and location along the barrel cavity length. Therefore, the spatial and length relationships between the barrel rails herein are described using the terms 'like' or 'similar' to include these minor variations. Examples follow. The power rail with forward current shunt continuity might be shortened at the breech or displace in the muzzle direction by the distance between the muzzle proximal edges of the forward and aft current shunts. The power rail with propulsion bus continuity might be shortened at its breech end or displace towards the muzzle the distance between the muzzle proximal edges of the armature's propulsion bus and aft current shunt. The barrel rail of the propulsion bus-aft shunt circuit, when extant, might be shortened at the muzzle by the distance between the muzzle proximal edges of the forward current shunt and propulsion bus continuity with said rail. The barrel bus length and location along the barrel cavity length might vary by as much as the width of a wall conductor at the breech and muzzle ends of the assembly; therefore, 'like' or 'similar' is used to reference the length and location of the wall conductor assembly's barrel bus.

[Para 66] ***Barrel Rail:*** A barrel rail is a conductor in the barrel cavity wall which is the parallel to the cavity's central axis or has a twist at constant radius about said axis and extends the length of the barrel of the invention and has continuous barrel cavity surface its length. The barrel rail has electrical continuity via said cavity surface with an element or elements of an armature in the barrel cavity.

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[Para 67] *Cavity Central Axis:* The cavity central axis is the line through the centroid center of the cavity area profile in all barrel cavity right sections.

[Para 68] *Circumscribes one or more time:* Physical encirclement of an object completely one or more times including additional fractions of complete encirclements when extant.

[Para 69] *Continuous Electrical Continuity:* Continuous electrical continuity is used to indicate low resistance electrical conductivity between electric current conducting elements in the armature or between electric conducting elements in the armature and electric current conducting elements in the barrel whether or not an the armature is stationary or moving.

[Para 70] *Electrical Isolation:* An electrically isolated element is limited in meaning to elements lacking low resistance electrical current paths to or through their neighbors. Magnetic and electric fields couplings are ignored.

[Para 71] *Forward wall conductors:* With an armature for the device in the barrel cavity, the forward wall conductors is each wall conductor of the group of one or more consecutive wall conductors that has at any instant continuous, or continuous sliding, electrical continuity via its contact means at the barrel cavity, with an armature's forward current shunt surface at the barrel cavity location of said contact means.

[Para 72] *LFMTB:* With reference to the direction a coil is wound or current path direction in a circuit or coil. Looking From Muzzle Towards Breech.

[Para 73] *Permanent Magnet Central Axis:* The permanent magnet's central axis is parallel or coincident its direction of magnetic polarization and through the centroid centers of its profile areas in right sections along its dimension that is parallel its direction of magnetic polarization.

[Para 74] *Power Rail:* A power rail is a barrel rail which has connection means for attachment, via an outside circuit, to a terminal of an outside power source.

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[Para 75] *Propulsion Bus:* A propulsion bus is a continuous conductor that is, between its two ends, oriented orthogonal to the armature's axis. The propulsion bus is in the armature, at, or in close proximity the armature's surface that is proximal the barrel cavity's wall surface when in the barrel cavity. When the propulsion bus includes a coil, each turn, is very slightly skewed to a right section plane. *e.g.* In a very tightly wound coil, when a right section plane of the armature is coincident with the muzzle side of the conductor (insulation) at the beginning of a turn it is coincident with the breech side of the conductor (insulation) at the end of the turn and the conductor turn while circumscribing the armature axis passes completely through said plane. When in the barrel cavity, the propulsion bus has at one end continuous electrical continuity with a barrel power rail and with armature movement said continuity is sliding. At its other end, the armature's propulsion bus has continuous electrical continuity with the propulsion bus-aft shunt circuit means or a second barrel power rail. The magnetic fields of the currents in the forward and aft wall conductors interact with the propulsion bus current causing armature's propulsion in the barrel's cavity.

[Para 76] *Propulsion Bus Coil:* An armature's propulsion bus's coil functions as a propulsion bus and is a continuous insulated conductor located in the armature between the armature's forward current shunt and aft current shunt. The propulsion bus's coil has a central axis about which it was wound and that in the armature is close and parallel or coincident with the armature's axis. The propulsion bus's coil is comprised of one or more turns about the armature's axis which circumscribe the central portion of the armature's body and each turn is in or proximal armature's surface that is proximal the barrel cavity's wall surface when in the barrel cavity. In designs utilizing an armature current bus as the propulsion bus-aft shunt circuit means, part of the last turn on the end of the propulsion bus's coil can be bent to extend to the armature aft current shunt and fastened thereto for continuous electrical continuity; *i.e.* forms the armature's current bus of the propulsion

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bus-aft shunt circuit means. Said last turn in other designs may be fastened for electrical continuity to an extension of the aft current shunt acting as the armature's current bus, or a separate conductor acting as said current bus. When the propulsion bus-aft shunt circuit means includes a third barrel rail and its electrical continuity with both the aft current shunt and propulsion bus of an armature in the barrel cavity, the second end of the propulsion bus's coil, [*i.e.* the final turn, a part of which may diverge from circumscribing the armature] has a surface, (with insulation removed) or is electrically continuous with a conducting surface which has electrical continuity with the barrel rail of the propulsion bus-aft shunt circuit means. Otherwise each end of the propulsion bus has electrical continuity with a barrel power rail.

[Para 77] ***Right section:*** A right section or right section plane is a plane which is perpendicular to [*i.e.* oriented orthogonal to] the central axis of a body or cavity.

[Para 78] ***Sliding Electrical Continuity:*** The meaning of sliding electrical continuity between elements in the invention is expanded herein to include arrangements to effect electrical continuity which use sets of conducting rollers or roller balls which are retained in and electrically continuous with one element and have low friction electrically conducting contact with a surface on the second element.

[Para 79] ***Twist:*** The cavity profile in right sections of a barrel cavity with twist taken at equal increments along the cavity axis length from breech to muzzle have to an axial reference plane increasing angular displacement about the cavity axis at a constant angular rate; *i.e.* $(\alpha_i - \alpha_0) / (d_i - d_0) = \text{constant}_{\text{barrel}}$, where α_0 and d_0 are the initial angle and distance, respectively, at the breech and both are 0. Angle α_i is the collective angular displacement of the cavity profile at cavity distance d_i from the breech; i.e. In right sections profiles of the barrel cavity with twist, the angular displacement with reference an axial reference plane of increment area elements of said barrel rails and wall conductor assembly

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at their fixed radii and angles to each other about the cavity axis, at, in or through the cavity surface, taken with reference a cavity right section at the breech increases with distance towards the muzzle from the reference section at constant rate: constant $_{barrel}$.

[Para 80] In an armature used in a barrel with twist, profiles of consecutive right sections taken at equal increments from breech end to muzzle end have, with reference an axial reference plane, increasing angular displacement about the armature axis at a constant rate per distance; *i.e.* $(\theta_i - \theta_0) / (L_i - L_0) = \text{constant}_{armature} = \text{constant}_{barrel}$ where θ_0 and L_0 are angle and distance, respectively, at the armature breech end and both are 0. Angle θ_i is the collective angular displacement of the armature profile at distance L_i from the armature breech end; i.e. In right section profiles of an armature with twist, the angular displacement of increment area elements at their fixed radii and angles to each other about the armature axis, with reference an axial reference plane the right section taken at the armature's breech end, increases with distance towards the armature muzzle end at a constant rate: constant$_{armature}$.

[Para 81] ***Wall Conductor:*** A wall conductor is a continuous conductor in the barrel cavity wall that is orthogonal the barrel cavity's axis and is at, in or proximal the surface of the barrel cavity throughout its length except where contoured to pass across a barrel rail with isolation. A wall conductor has at one end electrical continuity with the barrel bus of the wall conductor assembly and at its other end contact means at the barrel cavity. Said contact means has electrical continuity with an armature current shunt when said shunt is at the barrel cavity location of said contact means. The wall conductor is either, a single insulated conductor which nearly completely circumscribes the barrel cavity between its ends, or, includes a coil of one or more turns which circumscribes the barrel cavity between an end at the barrel bus and an end at the contact means at the barrel cavity. When the wall conductor includes a coil (or winding), each turn is very slightly skewed to a right section

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plane; *e.g.* In a very tightly wound coil, when a right section plane of the barrel cavity is coincident with the muzzle side of the conductor (insulation) at the beginning of a turn it is coincident with the breech side of the conductor (insulation) at the end of the turn and the conductor turn, and while circumscribing the barrel cavity, passes completely through said plane. The magnetic field of a conducting wall conductor interacts with an armature's propulsion bus current causing the armature's propulsion in the barrel cavity.

[Para 82] ***Wall Conductor's Coil:*** A wall conductor's coil functions as a wall conductor and is a continuous insulated conductor located in the barrel cavity wall at, in or proximal the barrel cavity's wall surface except where contoured to pass across a barrel rail with isolation. Each turn of a wall conductor's coil completely circumscribes the barrel cavity. The wall conductor's coil has a central axis (about which it was wound) that with the coil in the barrel cavity wall is close and parallel or coincident to the barrel cavity axis. The wall conductor's coil is comprised of one or more turns circumscribing the barrel cavity with each turn in or proximal the barrel cavity surface.

Discussion of the Drawings

[Para 83] **Figure 1** is a cutaway section view of an embodiment of patent application 10/707,607 and improvements thereof are the topic of this application. Shown to illustrate the current path and various elements essential to the propulsion of an armature through the barrel cavity, are armature 132 mounted in the barrel cavity 133 with the barrel cavity's shell removed.

[Para 84] Shown is a section of the wall conductor assembly 116 with its barrel bus 117 oriented parallel the cavity's axis. A plurality of wall conductors 118 extend from the barrel bus 117 whereat they have physical and electrical continuity and said wall conductors are orthogonal to the cavity's axis. The plurality of wall conductors 118 of the wall assembly in the assembled device are spaced apart from each other in a distribution from breech to

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muzzle in the wall of barrel cavity 133. Each wall conductor 118 is in, at or in close proximity the barrel cavity's wall surface except where it is deformed to avoid continuity with barrel rails and each wall conductor circumscribes most of the barrel cavity 133. Each wall conductor 118 has its end distal the barrel bus117 a contact means 119 at the barrel cavity 133.

[Para 85] Surface 136 of forward current shunt 134 of an armature 132 in the barrel cavity 133, whether stationary or in motion, has continuous electrical continuity with cavity surface 129 of the barrel power rail 130 and thereby the forward current shunt 134 has continuous electrical continuity with power rail 130.

[Para 86] Surface 136 of the forward current shunt 134 is at and whereat supplants and continues armature's guide 105. The armature 132 in the barrel cavity 133 has its guide 105 and forward current shunt's surface 136 in the mating channel in the cavity wall surface129 of barrel power rail 130 and therein maintains the armature's proper angular orientation about its axis in the barrel cavity.

[Para 87] Surface 135 of the forward current shunt 134 has continuous electrical continuity with the contact means 119 of each wall conductor 118 comprising the forward wall conductors at the barrel cavity location of said shunt's surface 135. The group of one or more wall conductors 118, at any instant, whose contact means 119 have electrical continuity with surface 135 of the forward current shunt 134 are the forward wall conductors.

[Para 88] Propulsion bus 141 is at the surface of the armature with an electrical insulting element 198 protecting it from electrically shorting to wall conductor contact means 119 at its barrel cavity location. Propulsion bus 141 is oriented orthogonal the armature axis and circumscribes most of the armature's body at its surface proximal the cavity wall's surface and the wall conductors therein. At one end of propulsion bus 141 is surface 140 which is

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at and whereat supplants and continues the armature's guide 106. Surface 140 has continuous electrical continuity with the barrel cavity surface 101 of the barrel rail 102 of the propulsion bus-aft shunt circuit means. At the other end of propulsion bus 141 is surface 142 which is at and whereat supplants and continues the armature guide 107. Surface 142 of armature's propulsion bus 141 has continuous electrical continuity with barrel cavity surface 126 of barrel power rail 127. The guide 107 and propulsion bus surface 142 of an armature 132 in the barrel cavity 133 is in and with armature movement travels in a mating channel in the barrel cavity wall surface 126 of barrel power rail 127 to maintain proper armature orientation in the barrel cavity.

[Para 89] Surface 139 of the aft current shunt 137 of an armature 132 in the barrel cavity 133, is at and whereat supplants and continues guide 106. Whether an armature in the barrel cavity is stationary or in motion, its aft current shunt's surface 139 has continuous electrical continuity with cavity surface 101 of barrel rail 102 and thereby the aft current shunt 137 maintains continuous electrical continuity with barrel rail 102 of the propulsion bus-aft shunt circuit means. Surface 138 of the aft current shunt 137 has continuous electrical continuity with the contact means 119 of each wall conductor 118 of the group of one or more wall conductors comprising the aft wall conductors, at any instant. The contact means of each wall conductor of the aft wall conductors is at the barrel cavity location of shunt surface 138.

[Para 90] The continuous electrical continuity of surface 140 of the propulsion bus 141 with cavity surface 101 of barrel rail 102, the barrel rail 102, and the continuous electrical continuity of surface 139 of the aft shunt 137 with surface 101 of barrel rail 102 comprise the propulsion bus-aft shunt circuit means in the device.

[Para 91] The guide 106 of an armature 132 in the barrel cavity 133, and propulsion bus surface 140, and aft current shunt surface 139 which are at and whereat supplant and

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continue armature guide 106, are in and, with armature movement, travel in a mating channel in the barrel cavity wall surface 101 of barrel rail 102 to maintain proper armature orientation in the barrel cavity.

[Para 92] Barrel rails 102,127 and 130 mount in rail subassembly 125 and which mounts in the barrel in assembly.

[Para 93] The current path in figure 1 with the power rail 130 attached to the positive terminal of an outside power supply and power rail 127 attached to the return terminal of said power supply is indicated by letters 'a' through 'm' and the magnetic fields, H, resultant current in forward and aft wall conductors through the armature's propulsion bus 141 are indicated at their radii, r.

[Para 94] The current path from 'a' to 'b' is in the muzzle direction in the barrel power rail 130 and at 'b' the path is from power rail 130 to forward current shunt 134 via the continuity of the rail's cavity surface 129 with surface 136 of the forward current shunt 134. The current path continues in the forward shunt 134 from 'b' to 'c' at the electrical continuity of forward current shunt surface 135 with contact means of 119 of wall conductors 118 comprising the forward wall conductors.

[Para 95] The current path continues with clockwise direction in the forward wall conductors from 'c' at contact means 119 of the forward wall conductors to'd' proximal the physical and electrical continuity of the forward wall conductors with the barrel bus 117 of wall conductor assembly 116 at 'e'.

[Para 96] The magnetic fields of the current in each wall conductor comprising the forward wall conductors, at any instant, interact with the current in the armature's propulsion bus 141 creating forces therein which have muzzle directed, cavity axis parallel components which propel the armature in the barrel cavity towards the barrel's muzzle; *i.e.* the magnetic fields of the current in each wall conductor 118 comprising the forward wall

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conductors, at any instant, interact with the propulsion bus current creating apparent forces of attraction there between.

[Para 97] The current path in barrel bus 117 is breech directed from 'e' to 'f'. The current path at barrel bus 117 continues from 'f' to each wall conductor 118 comprising the aft wall conductors at 'g' via said conductor's electrical and physical continuity with the barrel bus. The current path continues with a counter clockwise direction in each wall conductor 118 which at any instant is in the group of wall conductors comprising the aft wall conductors; i.e. the current path is from 'g' to 'h' in the figure and 'h' is at the electrical continuity of the contact means of the aft wall conductors with surface 138 of the aft current shunt.

[Para 98] The magnetic fields of the current in each wall conductor 118 comprising the aft wall conductors, at any instant, interacts with the current in the armature's propulsion bus 141 creating forces therein which have muzzle directed cavity axis parallel components which propel the armature in the barrel cavity towards the muzzle; *i.e.* the magnetic fields of each aft wall conductor's current interact with the propulsion bus current creating apparent forces of repulsion there between.

[Para 99] The current path in the aft current shunt 137 is from surface 138 to surface 139; i.e. from 'h' to 'i' in the figure. Surface 139 has continuous electrical continuity with cavity surface 101 of barrel rail 102 of the propulsion bus-aft shunt circuit means. The current path continues in the barrel rail 102 from said continuity at 'i', towards the muzzle, and to the continuity of said rail's cavity surface 101 with surface 140 of the armature's propulsion bus 141 at 'j'.

[Para 100] The current path continues in a clockwise direction in the propulsion bus 141 from the continuity of its surface 140 with barrel rail 102 of the propulsion bus-aft current shunt circuit means at 'j' under the insulator 198 to 'k' and therefrom in the propulsion bus

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to 'l' at the continuity of the propulsion bus's surface 142 with surface 126 of return power rail 127.

[Para 101] The current in the armature's propulsion bus 141, is acted on by the magnetic fields of the current in each wall conductor which, at any instant, is in the group of forward wall conductors or the group of aft wall conductors, creating forces in the propulsion bus with cavity axis parallel, muzzle directed components that propel the armature in the barrel cavity towards the muzzle.

[Para 102] The current path continues from the propulsion bus 141 to the power rail 127 in the breech direction via the electrical continuity of the propulsion bus's surface 142 with said power rail's cavity surface 126; *i.e.* from 'l' to 'm' in the figure. Power rail 127 is connected to the return terminal of the outside power supply.

[Para 103] The current flow in each wall conductor at any instant comprising the forward wall conductors and propulsion bus are always like directed about the armature axis and the current flow in each wall conductor at any instant comprising the aft wall conductors is always oppositely directed the current flow in the armature's propulsion bus; regardless the instant polarity of the barrel power rails; *i.e.* whether the current path is from 'a' to 'm' or 'm' to 'a' the forces created in the propulsion bus by the magnetic fields of the current in each wall conductor comprising either the forward or aft wall conductors at any instant always have cavity axis parallel, muzzle directed components.

[Para 104] **Figures 2 through 7** are of an embodiment of the invention using armatures whose propulsion bus includes a coil and a current bus as the device's propulsion bus-aft shunt circuit means. The device has a wall conductor assembly similar that in figure 1 and the armature's propulsion bus is in a series electrical circuit which includes the forward and aft wall conductors of the wall conductor assembly.

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[Para 105] With reference to the above force equation, the magnetic field of a current element I r_{WC} dθ at the intersection of an axis plane with a conducting wall conductor acts, at a distance d deflected an angle α to a cavity axis parallel ray through said current element, on a current element I r_{PB} dθ with equal current I at the intersection of said plane with a turn of the armature's propulsion bus coil.

[Para 106] With the propulsion bus coil wound in the conventional manner the values of distance, d, and Cos α between the wall conductor current element at an axis plane and a propulsion bus's coil turn current element in the same plane vary from one coil turn to the next and vary in each coil turn with angular displacement of said axis plane through the arc θ extent of the wall conductor.

[Para 107] The magnetic field at said axis plane's intersection with a turn of the propulsion bus coil is resolved in said plane into parallel and normal components to the armature axis and the normal components of the magnetic fields of a wall conductor current element interacts with the current element at the intersection of said plane with each turn of the propulsion bus creating forces in said propulsion bus turns with cavity axis parallel, muzzle directed components.

[Para 108] The current element at an axis plane's intersection with a turn of the propulsion bus is resolved into normal and parallel components to the axis plane and $\Delta I_{\perp}$ is the component of interest with which the magnetic field interacts:

$$\Delta I_{\perp} = [(TL^2 - CW^2)^{1/2} / TL](I)$$

where TL is the length of a propulsion bus turn and CW is the thickness of the insulated conductor comprising the propulsion bus.

[Para 109] Figure 2 is a view of an assembled shortened electromagnetic propulsion device 200 with an armature 232 for use therein at its breech end. The barrel has two structural sections, 211 and 211a, and indicated at the foreshortened barrel muzzle are the

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barrel cavity 233 and its barrel cavity shell 220 along with the barrel rail subassembly 225. Indicated near the breech end of the accelerator are the connection lugs 228 and 231 of power rails 227 and 230, respectively. To permit a more distinct definition of the parts relationship of accelerator 200 in figure 3, the accelerator 200 is shortened at its muzzle by three closely proximal right section planes through the barrel, one of which passes through the barrel sections 211 and 211a, the second through the wall conductor assembly 216, and the third through the shell 220 of the barrel cavity 333.

[Para 110] **Figure 3** is a view at a 15° angle up into the muzzle of accelerator 200. The barrel bus 217 of the wall conductor assembly 216 is shown sectioned and a wall conductor 218 is shown circumscribing the barrel cavity 233 in its orthogonal extension to the barrel cavity axis from the barrel bus 217. Said wall conductor circumscribes most of the barrel cavity 233 at the outer surface 220e of barrel cavity shell 220 and terminates in the barrel rail subassembly 225 whereat its contact means 219 extends to the barrel cavity through a mating opening 221 in the cavity surface 225i in the rail subassembly 225. Surface 225i is the rail subassembly's continuation of surface 220i of cavity shell 220. Shown is the plurality of wall conductor contact means 219 in their respective openings 221 through the barrel cavity surface 225i of the rail subassembly 225. The barrel power rail 227, its cavity surface 226 with its open guide way channel 226c and the barrel power rail 230, its cavity surface 229 with its open guide way channel 229c are indicated in their rail subassembly mountings. Also shown in figure three are the armature guide ways 203 and 203a in shell 220 of the barrel cavity 233. Guide ways 203 and 203a extend the length of the barrel cavity for location and travel therein of the guides 247 and 247a, respectively, of an armature 232 in the barrel cavity 233.

[Para 111] Discussing figure three with reference also to the armature in figures 5 and 6, with an armature 232 in the barrel cavity, contact means 219 at the armature's location in

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the barrel cavity 233 have contact with the armature's surface proximal the barrel cavity surface 225i of the rail subassembly. Each wall conductor 218 whose contact means 219 is on the muzzle side of the propulsion bus coil 241 and has continuous electrical continuity, at any instant, with surface 235 of the armature's forward current shunt 234 is one of the group of wall conductors comprising, at said instant, the forward wall conductors. Each wall conductors 218 whose contact means 219 is on the breech side of the propulsion bus coil 241 and has continuous electrical continuity, at any instant, with surface 238 of the armature's aft current shunt 237 is one of the group of wall conductors comprising, at said instant, the aft wall conductors.

[Para 112] Barrel rail subassembly 225 is shown in section along with its mounted barrel power rails 227 and 230 and their respective continuous barrel cavity surfaces 226 with channel 226c and 229 with channel 229c which extend the length of the rails. Channels 226c and 229c extend in the barrel cavity walls beyond the barrel power rails to the barrel cavity's breech and muzzle ends. Channels 226c and 229c along with channels 203 and 203a extend the length of the barrel. With an armature in the barrel cavity, the armature's guides 207 and 205 travel in open channel 226c in cavity surface 226 of power rail 227 and open channel 229c in cavity surface 229 of power rail 230, respectively, and therein maintain the armature's orientation. Also, with an armature 232 in the barrel cavity 233, surface 236 of the armature's forward current shunt 234 has continuous electrical continuity with barrel cavity surface 229 of power rail 230 and surface 242 of the propulsion bus coil 241 has continuous electrical continuity with barrel cavity surface 226 of power rail 227.

[Para 113] **Figure 4** is a view of the electromagnetic propulsion device 200 in figure 2, disassembled. Shown are the two halves, 211 and 211a, of the barrel structure which have at their interior surface channeling 210 and 210a, respectively. Rigidly retained in the

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channeling 210 of barrel section 211 is barrel rail subassembly 225 with barrel power rails 227 and 230 therein. Channeling 210 in barrel section 211 and channeling 210a in barrel section 211a in the assembly rigidly retain wall conductor assembly 216 and barrel cavity shell 220. Shown is the wall conductor assembly 216 with its distribution of wall conductors 218 spaced along the barrel bus 217 from breech to muzzle. Also shown are the barrel rail subassembly 225 which has a plurality of spaced openings 221 distributed along its barrel cavity surface length so that in the assembly each opening 221 has a contact means 219 of a wall conductor 218 through it. The power rails 227 and 230 with their connection lugs 228 and 231, respectively, are indicated and in the assembly are retained in barrel rail subassembly 225. Indicated also is barrel cavity surface shell 220 which is rigidly retained in the assembly within the wall conductor assembly 216 by the interior surfaces of channeling 210 and 210a of barrel wall sections 211 and 211a, respectively. Also shown in figure 4 at the breech end of the disassemble device is an armature 232.

[Para 114] **Figure 5** is a view of an armature 232 for the propulsion device 200. The armature's forward current shunt 234 with its surfaces 235 and 236 are indicated and surface 236 of the forward current shunt 234 is at armature guide 205 whereat it supplants and continues said guide's surface.

[Para 115] The armature's aft current shunt 237 with its surface 238 in the armature surface along with the electrically insulating encasement 241c of armature's propulsion bus 241 are indicated. Surface 242 of the propulsion coil 241 is indicated at guide 207 where it supplants and continues said guide's surface. Armature's guide 247a is also indicated. With an armature 232 mounted for propulsion through the barrel cavity 233, the armature's guide 205 is in mating channel 229c in the barrel cavity surface 229 of power rail 230, the armature's guide 207 is in mating channel 226c in the barrel cavity surface 226 of power

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rail 227, and armature's guides 247 and 247a are in barrel cavity guide ways, 203 and 203a, respectively.

[Para 116] Whether an armature 232 in the barrel cavity 233 is stationary or traversing the cavity, when the surface 235 of the armature's forward current shunt 234 is, at any instant, at the barrel cavity location of the contact means 219 of a wall conductor 218 the forward current shunt 234 has continuous electrical continuity with said wall conductor and said wall conductor is one of the group of wall conductors, at said instant, comprising the forward wall conductors. Said continuity is via the electrical continuity of surface 235 of the forward current shunt 234 with said wall conductor's contact means 219 through its mating barrel cavity opening 221.

[Para 117] In like circumstances, when the surface 238 of the armature's aft current shunt 237 is, at any instant, at the barrel cavity location of the contact means 219 of a wall conductor 218, the aft current shunt 237 has continuous electrical continuity with said wall conductor and said wall conductor is one of the group of wall conductors, at said instant, comprising the aft wall conductors. Said continuity is via the electrical continuity of surface 238 of the aft current shunt 237 with said wall conductor's contact means 219 through its mating barrel cavity opening 221.

[Para 118] Whether an armature 232 is stationary or traversing a barrel cavity 233, its forward current shunt 234 has continuous electrical continuity with barrel power rail 230 via the continuous electrical continuity of the forward current shunt's surface 236 with cavity surface 229 of power rail 230, and its propulsion bus coil 241 in encasement 241c has continuous electrical continuity with barrel power rail 227 via the continuous electrical continuity of the propulsion bus's surface 242 with the cavity surface 226 of power rail 227.

[Para 119] **Figure Six** is a view of the armature 232 in figure 5 disassembled. Shown is the forward armature section 232a which has in its surface open channel 250 in which

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mounts forward current shunt 234 with its armature surfaces 235 and 236 to provide electrical continuity between power rail 230 and the forward wall conductors of the wall conductor assembly. The forward shunt's surface 236 is at and whereat supplants and continues armature guide 205. Also indicated are the leading ends in the barrel cavity of guides 205 and 207 in armature section 232a.

[Para 120] The armature's aft section 232b has in its surface open channel 252 in which mounts aft armature current shunt 237. The armature's aft section 232b also has open channel 254 on which mounts, in the assembled armature, the propulsion bus coil 241 in its insulating encasement 241c. Aft current shunt 237 mounts in open channel 252 and channel 252 has opening 251 to open channel 254 which aligns, when the aft current shunt 237 is mounted in channel 252 with the aft current shunt's opening 239. Partially shown is the armature's propulsion bus coil in its sectioned away insulating casing 241c. One end of propulsion coil 241, indicated as 240, is bent parallel to the armature's axis so that in the assembled armature it extend through the aft armature section's channel 251 into - insulation is removed from this point on- opening 239 of the aft current shunt whereat it is fastened for electrical continuity with the aft current shunt 237. Said bent propulsion coil end 240 functions as the current bus of the propulsion bus-aft shunt circuit means in the topic device. The other end of the propulsion bus coil 241 in its casing 241c is bent up and over the casing to continue in the guide 207 which it supplants and continues and the coil's surface insulation is removed thereat revealing propulsion bus surface 242. With an armature in or traversing the barrel cavity 233, the propulsion bus's coil via its surface 242 has continuous electrical continuity with the barrel cavity surface 226 of power rail 227.

[Para 121] **Figure 7** is a cutaway sectioned view of the embodiment in figure 2, to illustrate the current path therein. Shown are the armature 232 circumscribed by a section of the wall conductor assembly 216 and said assembly's barrel bus 217 and wall conductors

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218. The wall cavity shell 220 is cut away except at the breech end of the figure. The barrel rail subassembly 225 is shown sectioned away as are the barrel power rails 227 and 230 mounted therein. A part of the armature 232 and encasement 241c of the propulsion bus coil 241 is also shown cut away (*i.e.* sectioned away). The current bus end 240 of the armature's propulsion bus coil 241 and its continuity with the aft current shunt 237 is indicted. Said bus end is the current bus of the propulsion bus-aft shunt circuit means. Also indicated is surface 242 of armature's propulsion bus 241 at its continuity with cavity surface 226 of the barrel power rail 227.

[Para 122] With barrel power rail 230 connected via its connection lug at the breech of the barrel to the positive terminal of an outside power supply, current direction in barrel rail 230 is towards the barrel's muzzle; *i.e.* from 'a' to 'b' in the drawing. Surface 236 of the forward current shunt 234 at its continuous electrical continuity with cavity surface 229 of power rail 230 is at 'b' in the drawings and the path from 'b' to 'c' is the current path from surface 236 to surface 235 of the forward current shunt 234 and the current path from 'c' to 'd' is from forward current shunt's surface 235 to each wall conductors 218 whose contact means 219 has electrical continuity with surface 235, at any instant, and is thereby, at said instant, one of the group wall conductors comprising the forward wall conductors.

[Para 123] The current path in each wall conductor, at any instant, comprising the forward wall conductors has a clockwise direction, LFMTB, and circumscribes a large part of the barrel cavity 233 and armature 232 therein while immediately forward the propulsion bus coil 441 in its encasement 241c; i.e. from 'd' to 'e' in the figure. The current path point 'e' is at the juncture of each wall conductor comprising, at any instant, the forward wall conductors with the barrel bus 217 of wall conductor assembly 216. The magnetic fields of the current in each wall conductors 218 in the group of wall conductors comprising, at any instant, the forward wall conductors interacts with the equal current in each turn of the

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armature's propulsion bus coil creating forces therein with cavity axis parallel, muzzle directed components.

[Para 124] The current path is from 'e' at the forward wall conductors' juncture with the barrel bus 217 to the barrel bus current path point 'f' thereat. The current path has breech direction in the barrel bus 217; i.e. from 'f' to 'g' in the figure. The current exiting the barrel bus is distributed to each wall conductor 218 comprising, at any instant, the aft wall conductors (i.e. each wall conductor whose contact means 219, at said instant, has electrical continuity with surface 238 of the aft current shunt) and, LFMTB, the current in each said wall conductor circumscribes the barrel cavity and armature therein in a counter clockwise direction from the barrel bus to the armature's aft current shunt's surface 238; i.e. from 'h' to 'i' to 'j' in the figure.

[Para 125] The current path from each wall conductor comprising the aft wall conductors is from 'i' to 'j' at the aft current shunt 237 via the continuous electrical continuity between contact means 219 of each said wall conductor of the group of wall conductors comprising the aft wall conductors at any instant and surface 238 of the aft current shunt 237 at said conductor's barrel cavity location.

[Para 126] The magnetic fields of the current in each wall conductor 218 which at any instant is in the group of wall conductors comprising the aft wall conductors interacts with the equal current in each turn of the armature's propulsion bus coil 241 in its encasement 241c creating forces therein with cavity axis parallel muzzle directed components.

[Para 127] The current path in the armature's aft current shunt is from 'j' to 'k' where 'k' is at the armature's current bus 240 of the propulsion bus-aft shunt circuit means and its continuous electrical continuity with the aft current shunt.

[Para 128] Current bus 240 is continuous with the armature's propulsion bus coil 241. Said coil is indicated at 'l' in the drawing. The propulsion bus coil's current path is

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clockwise; *i.e.* in the same direction as the current path in each wall conductor, at any instant, comprising the forward wall conductors and opposite the current path direction in each wall conductor, at said instant, comprising the aft wall conductors. The propulsion bus current path is from 'k' to 'l' to 'm' in the figure, where 'm' is at the continuous electrical continuity of surface 242 of the propulsion bus coil 241 with cavity surface 226 of power rail 227. The current path in power rail 227 has breech direction; i.e. from 'm' to 'n' in the figure. Barrel power rail 227 is connected via its breech end lug 228 to the return terminal of the outside power supply.

[Para 129] With the polarity of the power rails reversed the current in power rail 227 is muzzle directed from 'n' to 'm' whereat at said rail's cavity surface 226 has continuous electrical continuity with surface 242 of the propulsion bus coil 241. The current direction in the propulsion bus coil is counter clockwise and continues from the propulsion bus coil 'l' to 'k' at the armature's current bus 240 of the propulsion bus-aft shunt circuit means and from 'k' to 'j' at the surface 238 of aft current shunt 237 and its continuous electrical continuity with the contact means 219 of each of the wall conductors, at any instant, comprising the aft wall conductors. The current path in each wall conductor comprising the aft wall conductors, at any instant, has clockwise direction about the barrel cavity and the armature therein; *i.e.* from 'i' to 'h' in the figure. The magnetic fields of the current in each wall conductor comprising the aft wall conductors at any instant interacts with the equal currents in each turn of the armature's propulsion bus coil 241 in its encasement 241c creating forces therein with muzzle directed, cavity axis parallel components which propel the armature in the barrel cavity towards muzzle. The current continues from the wall conductors 218 comprising the aft wall conductors, any instant, to the wall assembly's barrel bus 217 wherein it muzzle directed; *i.e.* the current is from 'h' at the aft wall conductors' juncture with the barrel bus to 'g' in the barrel bus at said juncture and from 'g'

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to 'f' in the barrel bus. The current continues from the barrel bus in distribution to each wall conductor 218 whose contact means at any instant has electrical continuity with surface 235 of the forward current shunt 234, and is thereby at said instant one of the group of wall conductors comprising the forward wall conductors; *i.e.* the current passes from the barrel bus at 'f' to the bus's juncture with the forward wall conductors at 'e'. The current's direction in each wall conductor in the group of wall conductors comprising the forward wall conductors is, as in the propulsion bus coil, counter clockwise; *i.e.* in the figure from 'e' to 'c'. The magnetic fields of the current in each wall conductor of the forward wall conductors also interacts with the equal currents in each turn of the armature's propulsion bus creating therein forces with cavity axis parallel, muzzle directed components that propel the armature in the barrel cavity towards the muzzle. The current continues from the forward wall conductors through their contact means 219 at the barrel cavity to surface 235 of the forward current shunt 234; *i.e.* from 'd' to 'c' in the figure. The current in the forward current shunt 234 is from surface 235 to surface 236 and the continuous electrical continuity surface 236 has with cavity surface 229 of barrel power rail 230; *i.e.* from 'c' to 'b' in the figure. The current in power rail 230 is breech directed; *i.e.* from 'b' to 'a' in the figure. The current exits the power rail 230 to the external power supply return terminal via said rail's lug 231. Regardless the direction of current flow in the circuitry of the device, an armature in the barrel cavity is always propelled from the cavity's breech to muzzle.

[Para 130] **Figure 8** is a cutaway section view of a device of the invention which uses coils as wall conductors. The wall conductor coils 318 have one or more turns about the barrel cavity 333 and its axis and in the assembly the wall conductor coils 318 are mounted in the channeling 310 and 310a of barrel sections 311 and 311a, respectively, with surface in and/or closely proximal the barrel cavity surface. The topic embodiment has an armature

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332 similar to the armature in figure 1 which has a propulsion bus 341 comprised of a continuous insulated conductor in the armature at the armature's surface and oriented orthogonal to and circumscribing the armature's axis.

[Para 131] With an armature in the barrel cavity 333, between the propulsion bus's end surface 340 at cavity surface 301 of the third barrel rail 302 whereat it has continuous electrical continuity and the propulsion bus's end surface 342 at the cavity surface 326 of barrel power rail 327 whereat it also has continuous electrical continuity, the propulsion bus circumscribes most of the armature. An auxiliary insulating element 398 is indicated in the figure and affords the propulsion bus further protection from continuity with wall conductor contact means 319 at their path across the propulsion bus's surface of an armature in the cavity. The continuous electrical continuity of cavity surface 301of barrel rail 302 with surface 339 of the aft current shunt 337, the barrel rail 302, and the continuous electrical continuity of end surface 340 of propulsion bus 341 with the cavity surface 301 of the barrel rail 302 comprise the propulsion bus-aft shunt circuit means in the device.

[Para 132] Between its end at the barrel bus 317 of the wall conductor assembly 316 and its end with contact means 319 at the barrel cavity each wall conductor coil 318 is in an optional rigid insulating encasement 318c. The magnetic wire of a wall conductor's coil, is itself insulated with non-bonding or self bonding material. The wall conductor coil when without encasement, is kept closely wound by self bonding insulation, the structure in which they mount, chemical binding or other methods known to practitioner of the relevant arts. The wall conductor coils in the figure are wound counter clockwise from their ends with contact means 319. Shown in the breech end of the figure are lug 331 of power rail 330 and lug 328 of power rail 327 to which circuitry from the terminals of an outside power supply connect.

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[Para 133] With an outside power supply's positive terminal connected to lug 331 and its return terminal connected to lug 328, the current is muzzle directed in power rail 330 to the forward current shunt 334 where said rail's cavity surface 329 has continuous electrical continuity with surface 336 of said shunt. The current through shunt 334 is from its surface 336 to its surface 335 and the continuous electrical continuity surface 335 has via the contact means 319 with each wall conductor, at any instant, of the group of wall conductors comprising the forward wall conductors. The current continues in the coil of each wall conductor comprising the forward wall conductors in a counter clockwise direction, around the barrel cavity in each turn of said coil and the magnetic fields of the current element at the intersection of an axis plane within the arc extent of the propulsion bus 341 with each turn of said coil interacts with the current element at the intersection of said axis plane with the propulsion bus creating forces therein with cavity axis parallel, muzzle directed component.

[Para 134] The current continues from the coil of each wall conductor of the group of wall conductors, at any instant, comprising the forward wall conductors to the barrel bus 317 of wall conductor assembly 316 wherein it is breech directed. The current exits from the barrel bus 317 to each wall conductor 318 of the group of wall conductors 318 comprising the aft wall conductors, at said instant, and continues in a clockwise direction through each turn of each said wall conductor's coil about the barrel cavity and the magnetic fields of the current element at the intersection of an axis plane within the arc extent of the propulsion bus with each turn of said coil interacts with the current element at the intersection of said plane with the propulsion bus creating therein forces with cavity axis parallel, muzzle directed components.

[Para 135] The current continues to the aft current shunt 237 via the continuous electrical continuity of the contact means 319 of each wall conductor of the group of wall conductors,

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at any instant, comprising the aft wall conductors with surface 338 of the aft current shunt 337, and therein to surface 339 and said surface's continuous electrical continuity with the cavity surface 301 of barrel rail 302 of the propulsion bus-aft shunt circuit means. The current in barrel rail 302 is muzzle directed. The current passes from barrel rail 302 to the armature's propulsion bus via the continuous electrical continuity surface 301 of barrel rail 302 has with the end surface 340 of the propulsion bus 341. The third rail 302 and the continuous electrical continuities of its barrel cavity surface 301 with the aft current shunt surface 339 and the propulsion bus surface 340 comprise the propulsion bus-aft shunt circuit in the device.

[Para 136] The current continues through the arc extent of the propulsion bus 341 in a counter clockwise direction to said bus's end surface 342. The magnetic fields of the forward and aft wall conductors (coils) interact with the current in the propulsion bus creating forces in the propulsion bus with axis parallel, muzzle directed components that propel the armature 332 through the barrel cavity 333 towards the muzzle.

[Para 137] The current continues from the armature's propulsion bus 341 to the barrel power rail 327 via the continuous electrical continuity surface 342 of the propulsion bus 341 has with the barrel cavity surface 326 of power rail 327. The current in barrel power rail 327 is breech directed to connection lug 328 of power rail 327 in the breech end of the barrel. Lug 328 of power rail 327 is connected to the return terminal of the outside power supply.

[Para 138] When the current direction is reversed; *i.e.* the positive terminal of the power supply is connected to lug 328 and the power supply's return terminal is connected to lug 331, current direction in power rail 327 is towards the muzzle. The current passes from barrel rail 327 to the armature's propulsion bus 341 wherein it has a clockwise direction about the armature and wherein the magnetic fields of the forward and aft wall conductors

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(coils) interact with the propulsion bus current creating forces therein with cavity axis parallel, muzzle directed components which propel the armature in the cavity towards the muzzle. The current continues to the aft current shunt 337 via the third barrel rail 302 wherein it has a breech direction. The current passes from the armature aft current shunt 337 to the coil of each wall conductor 318 comprising, at any instant, the group of wall conductors comprising the aft wall conductors and traverses said coil in a counter clockwise direction about the barrel cavity -opposite the propulsion bus current direction- and the current traversing each said coil is one of the two sources of magnetic fields interacting with the propulsion bus current as discussed above. Current is from each wall conductor (coil) of the group of wall conductors comprising the aft wall conductors, at any instant, to the barrel bus 317 of the wall conductor assembly 316 and therein towards the barrel muzzle to the forward wall conductors. The current direction in the coil of each wall conductor 318 of the group of wall conductors comprising, at any instant, the forward wall conductors is clockwise about the barrel cavity - the same direction as the current in the propulsion bus- and the current traversing each said coil is the second source of magnetic fields interacting with the propulsion bus current. The current exits the forward wall conductors to the return power rail 330 via forward current shunt 334, and exits the device via terminal lug 331 which is connected to the return terminal of the outside power supply.

[Para 139] **Figures 9 through 12** are an embodiment of the invention with a cylindrical barrel cavity 433 and armatures 432 which are cylindrical, at least in part, for propulsion therein. In the topic design, wall conductor assembly 416 includes in its plurality of spaced wall conductors 418 distributed along its barrel bus from breech to muzzle, one or more wall conductors that have, between its end with contact means 419 at the barrel cavity and its end with physical and electrical continuity barrel bus 417, a coil which circumscribes the barrel cavity one or more time. The coil of each wall conductor 418 of the wall conductor

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assembly 417 is in an optional rigid insulating material encasement 418c mounted in mating channeling 410 and 410a of the barrel sections 411 and 411a, respectively.

[Para 140] The propulsion bus 441 in the armature 432 is at the armature cylindrical surface that in the barrel cavity 433 is proximal the cavity surface 420i of barrel cavity shell 420. The armature's propulsion bus 441 between its surface 440 proximal one end and its surface 442 proximal its second end, includes a coil about the armature axis which circumscribes the armature's body one or more times. With an armature 432 in the barrel cavity 433, its propulsion bus 441 has continuous electrical continuity with the third barrel rail 424 of the propulsion bus-aft shunt circuit means via the continuous electrical continuity of its surface 440 with cavity surface 423 of the barrel rail 424. Propulsion bus 441 also has continuous electrical continuity with the barrel power rail 427 via the continuous electrical continuity of its surface 442 with the cavity surface 426 of said rail.

[Para 141] **Figure 9** is a breech section view of the topic electromagnetic propulsion device, with barrel casing part 411 further sectioned away, most of the wall conductor assembly 416 removed and the cavity shell 420 sectioned away to show an armature 432 in the barrel cavity 433. Shown are the two barrel cavity sections 411 and 411a with channeling 410 and 410a, respectively, which in the assembly rigidly retain the wall conductor assembly 416, its wall conductor coils 418 in their encasements 418c and barrel cavity shell 420. The wall conductors 418 coils in their encasement 418c mount on barrel cavity shell exterior surface 420e in their spaced distribution along the length of the barrel cavity. The cavity shell 420 has an opening 421 through it into the barrel cavity 433 at each wall conductor 418 through which said wall conductor's contact means 419 extends to the barrel cavity. The power rails 427 and 430, with their connection means 428 and 431, respectively, extending through and out the cylindrical surface at the breech end of barrel section 411 along with third barrel rail 424 of the propulsion bus-aft shunt circuit means,

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are mounted and retained in the barrel cavity shell 420 and their continuous barrel cavity surfaces, 426, 429, and 423, respectively, are in and part of the barrel cavity shell inner surface 220i.

[Para 142] The barrel cavity surface also has guides extending its length for armature guide ways 447 and 447a used to maintain proper orientation of the armature during its barrel cavity traverse. With an armature in the barrel cavity 433 the armature's guides, 405, 406 and 407, in the armature's surface are located in the mating open channel 429c in cavity surface 429 of power rail 430, open channel 423c in cavity surface 423 of barrel rail 424, and open channel 426c of cavity surface 426 of barrel power rail 427, respectively, and also maintain the armature's proper orientation about the cavity axis. Open channels 429c, 423c and 426c extend the length of the barrel cavity; i.e. depending on design said open channels extend beyond the breech and muzzle ends of the barrel rails. The forward and aft current shunts, 434 and 437 at their location in armature's barrel cavity proximal surface and the propulsion bus surfaces 440 and 442 are also indicated in figure 9.

[Para 143] **Figure 10** is an assembled armature 432 for the electromagnetic propulsion device in figure 9. Indicated in the figure are the forward current shunt 434 with its surfaces 435 and 436 in the armature surface. Surface 436, is at and whereat supplants and continues armature guide 405. With the armature in the barrel cavity, forward current shunt's surface 436 is in and travels in mating channel 429c in cavity surface 429 of power rail 430 and therein has continuous electrical continuity with power rail 430.

[Para 144] While the forward current shunt's surface 435 is at the contact means 419 at the barrel cavity location of each wall conductor 418 of the group of wall conductors comprising the forward wall conductors, at any instant, and there is continuous electrical continuity between said contact means 419 and surface 435 of forward current shunt 434. Forward current shunt 434 has, via said continuity, continuous electrical continuity with

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each wall conductor of the group of wall conductors comprising the forward wall conductors, at any instant and there through with the wall conductor assembly 416.

[Para 145] The armature's propulsion bus 441 has surface 440 in the armature's surface at and whereat supplanting and continuing guide 406. With an armature 432 in the barrel cavity 433, armature's guide 406, along with propulsion bus surface 440, is in and travels in mating channel 423c in the cavity surface 423 of barrel rail 424 of the propulsion bus-aft shunt circuit means and the armature's propulsion bus 441 has continuous electrical continuity with barrel rail 424 via the continuous electrical continuity of said rail's cavity surface 423 with the propulsion bus's surface 440.

[Para 146] The armature's propulsion bus 441 has surface 442 in the armature's surface at and whereat supplanting and continuing guide 407. With an armature 432 in the barrel cavity 433, armature's guide 407, along with propulsion bus's surface 442, is in and travels in mating channel 426c in the cavity surface 426 of barrel power rail 427 and the armature's propulsion bus 441 has continuous electrical continuity with barrel power rail 427 via the continuous electrical continuity of said rail's cavity surface 426 with propulsion bus's surface 442.

[Para 147] Also Indicated in the figure are the aft current shunt 437 with its surfaces 438 and 439 in the armature's surface. Surface 439 is at and whereat supplants and continues guide 406. In the barrel cavity 433, guide 406 along with aft current shunt's surface 439, is in and travels in mating channel 423c in cavity surface 423 of the third rail 424 and aft shunt's surface 439 has continuous electrical continuity with said third rail. While the aft current shunt's surface 438 is at a wall conductor's contact means 419 barrel cavity location said wall conductor is one of the group of one or more wall conductors comprising the aft wall conductors, at any instant, and said contact means has continuous electrical continuity with said current shunt's surface. The aft current shunt 437, via said continuity, has

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continuous electrical continuity with the group of wall conductors comprising the aft wall conductors and there through with the wall conductor assembly 416.

[Para 148] Figure 11 is the armature in figure 11 disassembled. The aft part 432b of the armature 432 has open channel 452 in which aft current shunt 437 mounts and is retained in the assembled armature, and resilient insulating membrane 457 when located in open channel 452 under the aft current shunt provides resilient loading of the shunt's surface 438 to wall conductor contact means 419 at its barrel cavity location and the shunt's surface 439 to barrel cavity surface 423 of third rail 424. The coil of propulsion bus 441 mounts on shank 454 of the armature's aft section 432b and the aft portion of the armature 432b with propulsion bus mounted on shank 454 fits tightly into open channel 454a in the forward armature part 432a and is rigidly retained therein in the assembled armature.

[Para 149] The propulsion bus coil in wound in a clockwise direction, LFMTB; *i.e.* the propulsion bus 441 current path winds clockwise about armature shank 454 between surface 440 and 442. Both propulsion bus ends with surface 440 and 442 extend approximately the axial length of the propulsion bus coil and in the assembled armature are located in open channels 451 and 453, respectively, of the forward armature section 432a whereat surfaces 440 and 442 supplant and continue guides 406 and 407 respectively. The propulsion bus conductor's insulation is removed at surfaces 440 and 442. Also shown is auxiliary resilient insulating membrane 460 which when located between the propulsion bus's ends with surfaces 440 and 442 and the body of the propulsion bus coil effect an increased loading of said surfaces to the barrel cavity surfaces 423 of barrel rail 424 and 426 of power rail 427, respectively.

[Para 150] The forward part 432a of the armature 432 has open channel 450 in which forward current shunt 434 mounts and is retained in the assembled armature, and an auxiliary resilient insulating membrane 457 when located in open channel 450 under the

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forward current shunt provides resilient loading of the shunt's surfaces 435 to the contact means 419 of each wall conductor 418 at said shunt's barrel cavity location (i.e. each wall conductor of the group of wall conductors comprising the forward wall conductors) and the shunt's surface 436 to barrel cavity surface 429 of the barrel power rail 430.

[Para 151] **Figure 12** is a cutaway sectioned view of the electromagnetic propulsion device in figure 9 used to indicate the current path therein. In the figure, barrel cavity shell 420 is removed. The coils of the wall conductors 418 and the coil of the armature's propulsion bus 441are wound in a clockwise direction from their contact means 419 and the propulsion bus's surface 440, respectively. With connection lug 431 of barrel power rail 430 connected to the positive terminal of an outside power supply and connection lug 428 of barrel power rail 427 connected to the return or negative terminal of said power supply, the current path in the device is indicated in the drawing by the italic letters: *'a', 'b', 'c', 'd', 'e', 'f', 'g', 'h', 'i', 'j', 'k', 'l'* and *'m'*.

[Para 152] With power supplied to the device the current is muzzle directed from *'a'*, at lug 431, to *'b'*, at the continuous electrical continuity of surface 429 of barrel power rail 430 with surface 436 of the current shunt 434. The current continues from *'b'* to *'c'*, at the continuous electrical continuity of the forward current shunt's surface 435 with the contact means 419 of each wall conductor 418 of the group of wall conductors at said shunt's surface at any instant comprising the forward wall conductors. The current continues from *'c'* through *'d'* in the coil of each wall conductor in said group of wall conductors comprising the forward wall conductors wherein the path circumscribes the barrel cavity and armature therein a number of times in a clockwise direction and terminates at *'e'*, the juncture of each wall conductor at any instant comprising the forward wall conductors with the barrel bus 417of the wall conductor assembly 416. The magnetic fields of the current elements at the intersection of an axis plane with each turn -or fraction thereof- of the coil

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of each wall conductor of the forward wall conductor group at any instant act on each current element at said axis plane's interception with each turn -or fraction thereof- of the coil of the armature's propulsion bus 441, creating forces therein with muzzle directed, cavity axis parallel components; *i.e.* apparent forces of attraction there between.

[Para 153] The current in the wall conductor assembly's barrel bus 417 is breech directed from *'e'* to *'f'*. The current exits barrel bus 417 at *'f'*, to each wall conductors 418 of the group of wall conductors, at any instant, comprising the aft wall conductors and continues in the coils of said aft wall conductors at *'g'*, and therein circumscribes the barrel cavity 433 and armature 432 therein a number of times in a counter clockwise direction before exiting to the armature's aft current shunt 437 at *'h'* via the contact means 419 of each wall conductor of the group of wall, at any instant, comprising the aft wall conductors and the continuous electrical continuity each said contact means at said shunt's cavity location has with shunt's surface 438. The magnetic fields of the current elements at the intersection of an axis plane with each turn -or fraction thereof- of the coil of each wall conductor of the group of wall conductors comprising the aft wall conductors act on each current element at said axis plane's interception with each turn -or fraction thereof- of the armature's propulsion bus coil 441, creating forces therein with muzzle directed, cavity axis parallel components; *i.e.* apparent forces of repulsion there between.

[Para 154] The current continues in the aft current shunt 437 from *'h'* to *'i'* at the continuous electrical continuity of said shunt's surface 439 with the cavity surface 423 of barrel rail 424 of the propulsion bus-aft shunt circuit means. The current in barrel rail 424 is muzzle directed from *'i'* to *'j'* whereat rail surface 423 has continuous electrical continuity with surface 440 of the armature's propulsion bus. The current continues through the coil of the propulsion bus, *'k'*, and therein circumscribes the central body of the armature and the armature's axis a number of times in a clockwise and continues from there on to the

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propulsion bus surface 442, at *'l'*. The magnetic fields of the wall conductors which at any instant comprise the forward and aft wall conductors interact with the propulsion bus current circumscribing the armature propelling the armature in the barrel cavity from breech toward muzzle. Propulsion bus's surface 442 has continuous electrical continuity with the cavity surface 426 of barrel power rail 427. The current continues in power rail 427 towards the breech and thereat out of the device via lug 428, at *'m'*.

[Para 155] With the power connection to the power rail lugs reversed, current flows towards the muzzle in power rail 427 from *'m'* at lug 428 to *'l'* at surface 442 of armature's propulsion bus 441 wherein it continues in the propulsion bus coil, *'k'*, in a counter clockwise direction and wherein the magnetic fields of the wall conductors which at any instant comprise the forward and aft wall conductors interact with the propulsion bus's current creating forces therein which propel the armature in the barrel cavity 433 towards the muzzle. The current exits the propulsion bus to the barrel rail 424 at *'j'* where it continues in the breech direction to *'i'* at the armature aft current shunt 437 wherein it continues to *'h'* at the contact means of the each wall conductor, at any instant, at aft current shunt's surface 438 (i.e. each wall conductor of the group of wall conductors comprising the aft wall conductors). The path continues from *'h'* at the contact means of each said wall conductor, through *'g'*, each aft wall conductor's coil, wherein it encircles the barrel cavity and armature therein a number of times in a clock wise direction and then exits at *'f'* to the wall conductor assembly's barrel bus 417. The magnetic fields of the current elements at the intersection of an axis plane with each turn -or fraction thereof- of each said wall conductor's coil acts on each current element at said axis plane's interception with each turn -or fraction thereof- of the armature's propulsion bus coil, creating forces therein with muzzle directed, cavity axis parallel components; *i.e.* creating apparent forces of repulsion there between.

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[Para 156] The current in the barrel bus 417 is towards the muzzle from *'f'* to *'e'* at the juncture of the barrel bus with each wall conductor 418 of the group wall conductors at any instant comprising the forward wall conductors, in whose coil *'d'* the current continues in a counter clockwise direction and arrives at *'c'*, the electrical continuity of said wall conductor's contact means 419 with the forward current shunt surface 435. The magnetic fields of the current elements at the intersection of an axis plane with each turn -or fraction thereof- of each wall conductor of the group of wall conductors, at any instant comprising the forward wall conductors act on each current element at said axis plane's intersection with each turn -or fraction thereof- of the armature's propulsion bus 441 coil, creating forces therein with muzzle directed, cavity axis parallel components; *i.e.* creating apparent forces of attraction there between.

[Para 157] The current continues in the forward current shunt 434 from *'c'* to *'b'* where it enters barrel power rail 430 and therein is breech directed, exiting the device at *'a'*, at the connection of power rail lug 431 to circuitry to the return terminal of the outside power supply.

[Para 158] **Figures 13 through 18.** The electromagnetic propulsion designs discussed to this point have had the armature's propulsion bus and the wall conductor assembly's forward and aft wall conductors as elements in a series circuit; therefore, the wall conductor current therein has been limited to the maximum current that can pass through an armature's propulsion bus with its limitations on mass and volume by armature design constraints such as payload, mass, muzzle velocity, *etc.* Except when the barrel mass is limited by a requirement for high portability such as in a hand held gun type devices of the inventions, the wall conductor current capacities alone could be many times that of an armature for the device. To take advantage of the possibility for much larger current in the barrel wall conductors and the resultant greater magnetic fields densities interacting with

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armature's propulsion bus current to propel the armature in the barrel cavity, the propulsion devices have separate power supply circuits for the armature and the wall conductors in the following designs and the power is supplied to the two circuits in the devices by 2 pairs of barrel power rails not both the same; i.e. three or four power rails.

[Para 159] **Figure 13** electromagnetic propulsion device has its barrel casing removed along with the barrel cavity shell 520 and the wall conductors 518 in their insulating encasements 518c, at the armature's location in barrel cavity 533. The cavity shell 520 has at its breech end base 520b of enlarged radius which mounts in the breech end of the barrel casing and through which extend radially connection lugs 531, 528 and 525 of barrel power rails 530, 527 and 524, respectively. Said lugs extend radially through the barrel casing to outside the assembled device for connection to outside power sources and are shown cut short. Both the armature's propulsion bus coil and the wall conductors' coils are wound clockwise from surface 540 and contact means 519, respectively.

[Para 160] When lug 531 of power rail 530 is connected to the positive terminal of an outside high current power source and lug 525 of power rail 524 is connected to the positive terminal of a lower current power source, and the lug 528 of the barrel power rail 527 which is common to both circuits is connected to both return terminals of said power sources, the wall conductor circuit and the armature's propulsion bus circuit are, with an armature 532 in the barrel cavity 533, complete. With the power sources on, the current path through the armature's propulsion bus 541 is from lug 525 to power rail 524 wherein its direction is towards the muzzle. The current path continues from the power rail 524 to the armature's propulsion bus 541 via the continuous electrical continuity of said power rail's cavity surface 523 with armature's propulsion bus surface 540 at the power rail 524. The current path continues in the coil of the armature's propulsion bus 541 circumscribing the armature's body and axis clockwise, and the current therein interacts with the magnetic

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fields of the current in the forward and the aft wall conductors creating forces on the armature with cavity axis parallel, muzzle directed components. The current path continues from the propulsion bus 541 to the barrel power rail 527 via the continuous electrical continuity of the propulsion bus's surface 542 with the cavity surface 526 of power rail 527. The current path in barrel power rail 527 is breech directed and exits the devices via the connection of lug 528 to the return terminal of the armature's circuit power source.

[Para 161] The current path through the forward and the aft wall conductors is in power rail 530 from its connection lug 531 at the breech towards the muzzle. The path continues from power rail 530 to the armature's forward current shunt 534, via the continuous electrical continuity of said shunt's surface 536 with the cavity surface 529 of barrel power rail 530. The current path continues in the forward current shunt from its surface 536 to its surface 535 and therefrom to the forward wall conductors, via the continuous electrical continuity surface 535 has with contact means 519 of each wall conductor 518 of the group of one or more wall conductors comprising the forward wall conductors, at any instant. The current path in the forward wall conductors continues from contact means 519 at the barrel cavity, through the wall conductor's coil wherein the path circumscribes the barrel cavity and armature therein a number of times in the clockwise direction, before exiting to the barrel bus 517 of the wall conductor assembly 516. The magnetic fields of the current in the coils of the forward wall conductors interacts with the current in the coil of the propulsion bus 541creating forces in the propulsion bus with cavity axis parallel, muzzle directed components that propel the armature in the barrel cavity towards the muzzle; *i.e.* apparent forces of attraction between the propulsion bus and the forward wall conductors are extant.

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[Para 162] The current path in the barrel bus 517 continues towards the breech and exits therefrom to wall conductors 518 of the aft wall conductors. The current path continues in the coil of each wall conductor in the group of wall conductors comprising, at any instant, the aft wall conductor, circumscribing a number of times the barrel cavity 533 and armature 532 therein in a counter clockwise direction and continues therefrom to the armature's aft current shunt 537 via the continuous electrical continuity of said shunt's surface 538 with the contact means 519 of each wall conductor of the group of wall conductors comprising the aft wall conductors at any instant. The magnetic fields of the current in the coil of each wall conductor comprising the aft wall conductors interacts with the current in the coil of the propulsion bus 541 creating forces in the propulsion bus with cavity axis parallel, muzzle directed components that propel the armature in the barrel cavity towards the muzzle; *i.e.* apparent forces of repulsion between the propulsion bus and the aft wall conductors are extant. The current path in the armature's aft current shunt 537 continues from shunt surface 538 to shunt surface 539 and therefrom to barrel power rail 527 via the continuous electrical continuity of said shunt's surface 539 with cavity surface 526 of power rail 527. The current path in power rail 527 is breech directed to lug 528 of power rail 527. Lug 528 is connected to the return terminal of the circuit's external high current power source.

[Para 163] When the outside power sources have their positive terminal connected to the common power rail 527 of the device, the current path is from the power source supply for the armature through lug 528 into power rail 527. The current path in power rail 527 is muzzle directed and therefrom continues into the armature's propulsion bus 541 via the continuous electrical continuity of said propulsion bus's surface 542 with cavity surface 526 of power rail 527. The current path in the propulsion bus's coil circumscribes the armature axis and body a number of times in a counter clockwise direction and therein the magnetic

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fields of the current circulating in the current paths in the forward and aft wall conductors interact with the current in said propulsion bus path creating forces therein with muzzle directed, cavity axis parallel components. The current path exits the coil of propulsion bus 541 to barrel power rail 524 via the continuous electrical continuity said bus's surface 540 has with the cavity surface 523 of barrel power rail 524. The current path continues in power rail 524 towards the breech and therefrom through lug 525 to the negative, or return terminal of the armature's outside low current power source.

[Para 164] The current path for the wall conductor circuit is from the positive terminal of the outside high current power source for said circuit through lug 528 to the power rail 527 and therein towards the muzzle. The current path continues from power rail 527 to aft current shunt 537 via the continuous electrical continuity of said rail's cavity surface 526 with the aft shunt's surface 539. The current path continues from the aft current shunt 537 to each wall conductor of the group of wall conductors comprising the aft wall conductors at any instant via the continuous electrical continuity of aft current shunt's surface 538 with the contact means 519 of each of said wall conductors comprising the aft wall conductors. The current path continues in each aft wall conductor's coil in a clockwise direction about the barrel cavity and the armature therein and exits therefrom to the barrel bus 517 of the wall conductor assembly 516. The magnetic fields of the current in the coils of each wall conductor comprising the aft wall conductors interacts with the current in armature's propulsion bus coil creating forces therein with cavity axis parallel, muzzle directed components; *i.e.* apparent forces of repulsion between the propulsion bus and the aft wall conductors are extant..

[Para 165] The current path continues in the barrel bus towards the muzzle and therefrom into the coil of each wall conductor of the group of wall conductors comprising at any instant the forward wall conductors wherein it circumscribes the barrel cavity and armature

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therein a number of times in the counter clockwise direction. The magnetic fields of the current in the coil of each wall conductor comprising the forward wall conductors, at any instant, interact with the current in the armature's propulsion bus coil creating forces therein with cavity axis parallel, muzzle directed components; *i.e.* apparent forces of attraction between the propulsion bus and the forward wall conductors are extant. The current path continues from the coil of each wall conductor comprising the forward wall conductors, at any instant, to the armature's forward current shunt 534, via the continuous electric continuity of the contact means 519 of each said wall conductor comprising the forward wall conductors, at any instant, with surface 535 of the forward current shunt 534. The current path continues from the forward current shunt 534 to barrel power rail 530 via the continuous electrical continuity of forward current shunt's surface 536 with the cavity surface 529 of power rail 530. The current path in the power rail 530 is towards the breech and from there, via power rail lug 53, to the negative, or return, terminal of the high current power supply for the wall conductor circuit.

[Para 166] **Figure 14** is an armature 532 for the embodiment in figure 13 with the armature surface at the coil of the armature's propulsion 541partially cutaway. Indicated are the propulsion bus 541, surfaces 540 and 542 at and whereat supplanting and continuing the armature guides 507 and 506, respectively. Forward current shunt 534 with surface 535, that in the barrel cavity has continuous electrical continuity with contact means 519 of wall conductor 518 at said shunt barrel cavity location comprising the forward wall conductors, is indicated along with forward current shunt surface 536 at and whereat supplanting and continuing the armature guide 505. Forward current shunt surface 536 has continuous electrical continuity in the barrel cavity 533 with cavity surface 529 of barrel power rail 530. Also indicated are the armature's aft current shunt 537 with surface 538 that in the barrel cavity has continuous electrical continuity with the contact means 519 of

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wall conductors 518 at said shunt's barrel cavity location, comprising the aft wall conductors. The aft shunt's surface 539 at and whereat supplanting and continuing armature guide 506 is indicated. In the barrel cavity 533, surface 539 of aft current shunt 537 has continuous electrical continuity with cavity surface 526 of barrel power rail 527.

[Para 167] **Figure 15** is another embodiment of the invention with separate current supply circuits for the armature's propulsion bus and wall conductors. Although the embodiment has a fourth power rail, it has the advantage of permitting greater isolation between the two power circuits and requires far less complex power supplies and circuits therefrom. Shown is a breech section of the barrel cavity shell 620 with outer shell surface 620e and its inner shell surface 620i, the barrel cavity surface. The barrel casing sections 611 and 611a have been removed, and the barrel cavity shell 620 along with wall conductors 618 in their insulating structural encasement 618c mounted on the outer surface 620e of cavity shell 620 have been sectioned away at the armature's location in the barrel cavity, 633. There are two pairs of power rails, the first pair 627 and 630 with connection lugs 628 and 631, respectively, for connection to an outside high current power source are used by the wall conductor circuit and the second pair 681 and 624 with connection lugs 682 and 625, respectively, to an outside low current power supply is used by the armature's propulsion bus circuit. The barrel cavity surfaces 626 and 629 of the first power rail pair 627 and 630, respectively, are located approximately diametric across the barrel cavity 633 from the cavity surfaces 623 and 680 of the second power rail pair, 624 and 681, respectively. The power rails are so located to reduce the possibility of arcing between conducting elements of the two circuits due to dirt and/or moisture in the barrel cavity. Armature surface at the armature's propulsion bus coil is sectioned away to indicate the propulsion bus coil location and its continuity via surface 640 with power rail 624.

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[Para 168] **Figures 16 through 18** illustrate embodiments of the invention used as a bi-directional powered actuator or motor. With the wall conductor circuit and its conducting circuit elements separate and isolated from the armature's propulsion bus's circuit and its conducting elements, the direction of the powered traverse of the barrel cavity by an armature can be reversed by reversing the power source polarities at the input terminals of either the propulsion bus circuit or the wall conductor circuit. Therefore an armature in the barrel cavity can be used, not only as a projectile, but also as a powered bi-directional actuator piston or motor armature retained in the barrel cavity for many cycles of service.

[Para 169] **Figure 16** is an embodiment of the invention similar to figure 13 but used as an actuator or motor. The armature 732 has a shaft 790 extending axially from its muzzle end with connection means 791. The shaft 790 is shortened in the drawing by sectioning. The armature's propulsion bus 741 includes a coil that is wound clockwise from its breech end surface 742, at barrel cavity surface 723 of power rail 724 whereat it has continuous electrical continuity, to surface 740 at the muzzle end of the coil located at surface 726 of power rail 727 whereat it also has continuous electrical continuity. Barrel power rails 724 and 727 of the armature's propulsion bus circuit have connection lugs 725 and 728, respectively, which the isolated low current power source terminals external the invention connect. The armature's circuit in the invention is comprised of lug 725, power rail 724, cavity surface 723 of power rail 724, and its continuous electrical continuity with surface 742 of armature's propulsion bus 741, the armature's propulsion bus 741and its included coil -wound clockwise from breech end to muzzle end- the armature's propulsion bus surface 740, the continuous electrical continuity of surface 740 with cavity surface 726 of barrel power rail 727, barrel power rail 727, and said power rail's connection lug 728 at the breech end of the barrel.

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[Para 170] When the power lug 725 is connected to the positive output terminal of the low current isolated power source for the armature circuit -which includes current limiting means- and power lug 728 is connected to the return terminal of said power source, current flow in the coil of the armature's propulsion 741 is clockwise. When the power lug 725 is connected to the return terminal of said power source, and the power lug 728 is connected to the positive terminal of said power source, current flow in the coil of the armature's propulsion bus 741is counter clockwise.

[Para 171] The wall conductor circuit in the invention is comprised of: lug 731, power rail 730, barrel cavity surface 729 of said power rail, and its continuous electrical continuity with surface 736 of the armature's forward current shunt 734, forward current shunt's surface 735 and its continuous electrical continuity via contact means 719 with wall conductors comprising the forward wall conductors, at any instant, the coils of said wall conductors which circumscribe the barrel cavity 733 and the armature 732 therein a number of times, in a counter clockwise direction from their ends with contact means 719 to their ends with physical and electrical continuity with barrel bus 717 of the wall conductor assembly 716, the barrel bus 717 of the wall conductor assembly 716, each wall conductors of the group of wall conductors comprising the aft wall conductors, at said instant, the coils of said wall conductors which circumscribe the barrel cavity 733 and the armature 732 therein a number of times in a clockwise direction from the physical and electrical continuity of each said wall conductor at its end at the barrel bus 717 to its contact means 719 at the barrel cavity with continuous electrical continuity with surface 738 of the armature's aft current shunt surface, the aft current shunt, and said shunt's surface 739 with continuous electrical continuity with the cavity surface 726 of barrel power rail 727, the power rail 727 and said power rail's lug 728 to outside the device for connection to the terminal of the outside high current power source.

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[Para 172] When the power lug 731 is connected to the positive output terminal of the isolated high current power source for the wall conductor circuit and power lug 728 is connected to the return terminal of said power source, current path in the coil of each wall conductor comprising the forward wall conductors, at any instant, circumscribes the barrel cavity and armature therein a number of times in a counter clockwise direction, then continues through the barrel bus in the breech direction, and into the coil of each wall conductor comprising the aft wall conductors, at said instant, wherein it circumscribes the barrel cavity and armature therein a number of times in a clockwise direction. The current path continues via the continuous electrical continuity of contact means 719 of each said wall conductor with surface 738 of aft current shunt 737 and therefrom to power rail 727 via the continuous electrical continuity of said shunt's surface 739 with the cavity surface 726 of power rail 727 and from power rail 727 to outside the device via lug 728 which is connected to the return or negative terminal of the outside high current power source.

[Para 173] With lug 725 connected to the positive output terminal of the low current power supply for the armature circuit and lug 728 connected to the said power supply's return terminal, current in propulsion 741 bus coil is clockwise and the magnetic field of current in the forward wall conductors and the aft wall conductors interacts with the current in the propulsion bus creating therein forces with breech directed, cavity axis parallel component; *i.e.* apparent forces of repulsion between each forward wall conductor's coil and propulsion bus coil and apparent forces of attraction between each aft wall conductor's coil and the propulsion bus coil are extant.

[Para 174] When power lug 728 is connected to the positive output terminal of the isolated high current power source for the wall conductor circuit and power lug 731 is connected to the return terminal of said power source. The current flow in the coil of each wall conductor comprising the aft wall conductors, any instant, is in the counter clockwise direction, the

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current direction in the barrel bus 717 is towards the muzzle and the current in the coil of each wall conductor comprising the forward wall conductors, at said instant, is in the clockwise direction. The magnetic fields of the currents in the aft wall conductors interacts with the current in the coil of the armature's propulsion bus 741 creating therein forces with muzzle directed, cavity axis parallel components. The magnetic fields of the current in each wall conductor comprising the forward wall conductors interact with current in the armature's propulsion bus 741 creating therein forces therein with cavity axis parallel, muzzle directed components; *i.e.* apparent forces of repulsion between each aft wall conductor's coil and the propulsion bus coil and forces of attraction between each forward wall conductor's coil and the propulsion bus coil are extant.

[Para 175] While lug 728 is positive with reference lug 725, the armature's propulsion bus current is counter clockwise and the armature's directions of propulsion indicated above with the given wall conductor circuit polarities are reversed.

[Para 176] **Figure 17** is the armature 732 of the device in figure 16, with the armature's shaft extension 790 with connection means 791 shortened by section indicated. Elements 792 are roller ball elements which travel in mating cavity axis parallel raceways in the cavity surface 720i of the cavity shell 720 and maintain low friction alignment of the armature in the barrel cavity. The armature's surface at the coil of the propulsion bus 741 is cut away showing the coil and the armature's propulsion bus surfaces 740 and 742 at the coil's ends which are at and whereat supplant and continue guides 706 and 707, respectively. The coils end surfaces 740 and 742 of the propulsion bus 741, in the barrel cavity have continuous electrical continuity with barrel cavity surface 726 and 723 of barrel power rails 727 and 724, respectively.

[Para 177] **Figure 18** is an actuator or motor version of the embodiment in figure 15 showing a section of the device at the breech with the barrel casing sections 811 and 811a

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removed and the barrel cavity shell 820 and wall conductors 818 in their encasements 818c sectioned away at the location of armature 832 in the barrel cavity 833. Low friction roller balls 892 in the armature travel in cavity axis parallel raceways 893 in the cavity surface 820i of cavity shell 820. The actuator rod or armature extension 890 on the muzzle end of armature 832 is indicated along with its connection means 891.

[Para 178] Power rails 827 and 830 with connection lugs 828 and 831, respectively, for connection to a high current external power source for the wall conductor circuit are indicated along with cavity surface 826 of power rail 827 and cavity surface 829 of power rail 830 of said circuit. Indicated is the forward current shunt 834 and its surface 835 which has continuous electrical continuity with contact means 819 of the wall conductors comprising the forward wall conductors, at any instant. Surface 836 of forward current shunt 834 has continuous electrical continuity with the barrel cavity surface 826 of power rail 827. The aft current shunt 837 is indicated along with its surface 838 which has continuous electrical continuity with contact means 819 of the wall conductors comprising the aft wall conductors, at said instant. Aft current shunt's surface 839 has continuous electrical continuity with cavity surface 829 of barrel power rail 830.

[Para 179] Barrel power rail 824 and 881 which supply power to the coil of the propulsion bus circuit are indicted at the breech end of the barrel cavity 833 along with their barrel cavity surfaces 823 and 880. With the complete separation of the set of power rails in the armature's propulsion bus circuit and from the set of power rails in the wall conductor circuit in this actuator or motor embodiment less design sophistication is required in the external power sources for the two said circuits.

[Para 180] **Figures 19 through 23** are of embodiments and elements thereof wherein the armature's propulsion causing means is comprised of a permanent magnet polarized in the cavity axis direction and with its center in the cavity axis and mounted in the armature

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forward of the armature's aft current shunt and aft of the armature's forward current shunt and with its central axis coincident the armature's central axis. The magnet as the armature's propulsion causing means replaces the armature propulsion means in the preceding embodiments comprised of armature's propulsion bus and associated circuit elements including propulsion bus-aft shunt circuit means, power rails, connection lugs, and power source.

[Para 181] **Figure 19** is a breech end section of an electromagnetic propulsion device used to propel armature projectiles 32 with polarized permanent magnets as their propulsion causing elements. The barrel is comprised of two casing sections 11 and 11a which have channeling 10 and 10a in which mount the plurality of spaced wall conductors 18 in their individual auxiliary encasements 18c. Said wall conductors are distributed from breech to muzzle along the barrel bus 17 of the wall conductor assembly 16 and they each have physical and electrical continuity at one end with said bus. The inner circumference of coil of each wall conductor 18 in its encasements 18c mount on the outer surface 20e of the casing shell 20, and the shell 20 mounts in and is retained by the inner circumference surface of the assembled barrel casing sections 11 and 11a. The barrel cavity 33 is enclosed by the barrel cavity shell comprised of two parts 20 and 20a. Barrel cavity shell half 20a is cut away and the coils of the wall conductors removed to show the armature 32 in barrel cavity 33.

[Para 182] An openings 21in the barrel shell half 20a is at each wall conductor 18 and extend through guide 80 in the barrel cavity surface 20i into the barrel cavity 33. The contact means 19 at the end of each wall conductor coil 18 extends through the opening 21 at its cavity shell 20 location to the barrel cavity 33 for continuous electrical continuity therein with armature current shunt surfaces at its barrel cavity location. Continuous electrical continuity between a wall conductor and an armature's forward current shunt 34 is

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extant when said shunt's surface 35 is at the barrel cavity location of contact means 19 of said wall conductor and when so said wall conductor 18 is one of the group of one or more wall conductors, any instant, comprising the forward wall conductors. Continuous electrical continuity between a wall conductor and an armature's aft current shunt 37 is extant when said shunt's surface 38 is at the barrel cavity location of the contact means 19 of said wall conductor and when so, said wall conductor 18 is one of the group of one or more wall conductors comprising the aft wall conductors, a any instant.

[Para 183] The cavity shell 20a has channels 79 and 81 throughout its length which are parallel the cavity axis and in which are mounted power rails 27 and 30, respectively. With an armature 32 in the barrel cavity 33, power rail 27 is in and travels in guide way 77 in the armature's surface and the cavity surface 26 of barrel power rail 27 in armature channel 77 has continuous electrical continuity with surface 39 of the aft current shunt 37 which whereat supplants and continues channel 77. Also, power rail 30 is in and travels in guide way 75 in the armature's surface and its barrel cavity surface 29 therein has continuous electrical continuity with surface 36 of the forward current shunt 34 which whereat supplants and continues guide way 75. The armature's forward current shunt 34 has surface 35 at and whereat supplanting and continuing guide way 76 and the armature's aft current shunt 37 has surface 38 at and whereat supplanting and continuing guide way 76.

[Para 184] The armature guide 80 in the cavity inner surface 20i through which an opening 21 extends to the barrel cavity at each wall conductor 18 with said conductor's contact means 19 therein, is in and travels in the guide way 76 of an armature 32 in the barrel cavity 33. The wall conductor 18 contact means 19 through guide 80 in armature guide way 76 at the barrel cavity location of the armature's forward and aft armature current shunts, 34 and 37, respectively, have continuous electrical continuity with said shunts' surfaces, 35 and 38, respectively. When an armature 32 is in the barrel cavity 33, the

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guides 57 and 57a in shell half 20 which are cavity axis parallel and extend the barrel cavity length, are in and travel in armature guide ways 47 and 47a, respectively, to maintain proper orientation of the armature during its traverse of the barrel cavity. At their breech ends, barrel power rails 30 and 27 have connection lugs 31 and 28, respectively.

[Para 185] With an armature in the barrel cavity and the positive terminal of an outside power source connected to connection lug 31, and the return terminal of said power source connected to connection lug 28, the current path in the device is from power lug 31 through power rail 30 towards the muzzle and therefrom to the armature forward current shunt 34 via the continuous electrical continuity the power rail's barrel cavity surface 29 has with surface 36 of forward current shunt 34 in armature guide way 75. The current path continues in the forward current shunt 34 from surface 36 to surface 35 in the armature guide way 76 wherein surface 35 has continuous electrical continuity with the contact means 19 of each wall conductors 18, comprising the forward wall conductors, at the instant location in the barrel cavity of the armature's forward current shunt. The current path (not the electron flow direction) in each forward wall conductor's coils, between its end with contact means 19 and its end with physical and electrical continuity the barrel bus 17 of the wall conductor assembly 16, circumscribes the barrel cavity and armature therein in a counter clockwise direction creating apparent magnetic fields in each forward wall conductor's coil with north pole towards the muzzle and south pole towards the breech.

[Para 186] The current path in barrel bus 17 is towards the breech and exits therefrom to each wall conductor of the group of one or more wall conductors comprising the aft wall conductors, with contact means 19 at and with continuous electrical continuity with surface 38 of aft current shunt 37 in guide way 76. The current path in the coil of each wall conductor comprising the aft wall conductors, between its end with contact means 19 and its end with physical and electrical continuity the wall conductor assembly's barrel bus 17,

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circumscribes the barrel cavity and armature therein in a clockwise direction creating apparent magnetic fields in the coil of each wall conductor comprising the aft wall conductors with north pole towards the breech and south pole towards the muzzle. The center of permanent magnet 41 in the armature is located between the forward and aft current shunt and with its north pole towards the muzzle and its south pole towards the breech in the topic design.

[Para 187] The armature magnet's north pole is attracted to the south pole of the coil of each wall conductor comprising the forward wall conductors propelling the armature towards the barrel cavity's muzzle and the armature magnet's south pole is repulsed by the south pole of the coil of each wall conductor comprising the aft wall conductors also propelling the armature towards the barrel cavity's muzzle. The current path continues in aft current shunt from surface 38 to surface 39 in armature guide way 77 wherein it has continuous electrical continuity with surface 26 of the barrel power rail 27. The current path in barrel power rail 27 is in the breech direction to lug 28 which is connected to the return terminal of the outside power source.

[Para 188] **Figure 20** is an assembled armature for propulsion in the device in figure 19. Channel 54 in the breech end of armature 32 has magnet 41 pressed and retained therein with center between the forward and aft current shunt locations along the length of the armature. Guide way 76 in the armature surface for barrel cavity surface guide 80 and contact means 19 of wall conductors 18 therein along with surfaces 35 and 38 therein of forward and aft current shunts, 34 and 37, respectively are indicated in the drawing. The armature surface guide ways 77 and 75 for the barrel power rails 27 and 30, respectively, are indicated along with surface 36 of the forward current shunt 34 in guide way 75 and surface 39 of aft current shunt 37 in guide way 77.

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[Para 189] Figure 21 is a view of the armature in figure 20 disassembled. Shown are the magnet 41 and cylindrical opening 54 in the breech end of armature 32 into which the magnet is pressed and retained. Also shown are the open channel 50 in the armature surface in which forward current shunt 34 mounts and open channel 52 in the armature surface in which aft current shunt 37 mounts.

[Para 190] Figure 22 is an embodiment as in 19 using an armature with a permanent magnet but as a bidirectional actuator. Armature 932 has four linear arrays of roller balls 992 distributed in its surface about and parallel its axis. The armature's roller ball arrays in the barrel cavity travel in bearing raceways 957, 957a, 957b and 957c in the surface 920i of barrel cavity shell halves 920 and 920a to maintain proper orientation of the armature during its low friction movement in the barrel cavity. The actuator armature's direction of propulsion in the barrel cavity is determined by the direction of current in the wall conductor circuit; *i.e.* the polarities of the outside power supply terminals connected to the connection lugs at the barrel breech. The actuator armature 932 has permanent magnet 41 with north pole oriented towards the muzzle end of the armature and with south pole towards the armature's breech end. In the figure, the actuator armature has extension 990 shortened by section with connection means 991.

[Para 191] With barrel power rail lug 931 connected to the positive terminal of the outside power source and power rail lug 928 connected to the negative or return terminal of the outside power supply, the current in the coil of each wall conductor 918 in the group of wall conductors comprising the forward wall conductors, at any instant, is counter clockwise about the barrel cavity 933 and the armature 932 therein and the apparent south pole of the coil of each said wall conductor, at said instant, is towards the breech and proximal the north pole of the armature's magnet creating forces of attraction there between propelling the armature towards the barrel cavity's muzzle.

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[Para 192] The current in the coil of each wall conductor 918 in the group of wall conductors comprising the aft wall conductors, at said instant, is clockwise about the barrel cavity 933 and the armature 932 therein and the apparent south pole of the coil of each said wall conductor, at said instant, is towards the muzzle and proximal the south pole of the armature's magnet creating forces of repulsion there between which also propel the armature towards the barrel cavity's muzzle.

[Para 193] With the barrel power rail lug 931 connected to the negative or return terminal of the outside power source and power lug 928 connected to the positive terminal of the outside power supply, the current in the coil of each wall conductor comprising the aft wall conductors, at any instant, is counter clockwise and the apparent north pole of the coil of each said wall conductor, at said instant, is directed towards the barrel cavity's muzzle and proximal the south pole of the armature's magnet creating forces of attraction there between which propel the armature towards the barrel cavity's breech.

[Para 194] The current in the coil of each wall conductor 918 comprising the forward wall conductors, at said instant, is clockwise and the apparent north pole of the coil of each said wall conductor, at said instant, is breech directed and proximal the north pole of the armature's magnet creating forces of repulsion there between which also propel the armature towards the barrel cavity's breech.

[Para 195] **Figure 23** is the armature 932 in the actuator in figure 22, with a slice cut away from its body to show the location of the permanent magnet in the armature. The power takeoff shaft 990, shortened by sectioning, with connection means 991 is indicated.

[Para 196] **Figure 24** is a view into the breech end of a section of a barrel that has a cavity with twist. Figure 24 is similar figure 3 but with twist. The armatures for the design in figure 24 have a twist identical to that of the barrel cavity and may have armature propulsion element comprised of either an energized propulsion bus coil with an armature

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current bus as the propulsion bus-aft shunt circuit means, or a permanent with polarization parallel the armature's axis.

[Para 197] Although the invention has been described herein with reference to the presently preferred embodiments, a great number of modifications, changes and alterations including alternative configurations of said embodiments are possible without departing from the spirit and scope of the invention as defined in the appended claims and equivalents thereof.

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